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A General Reference Work on

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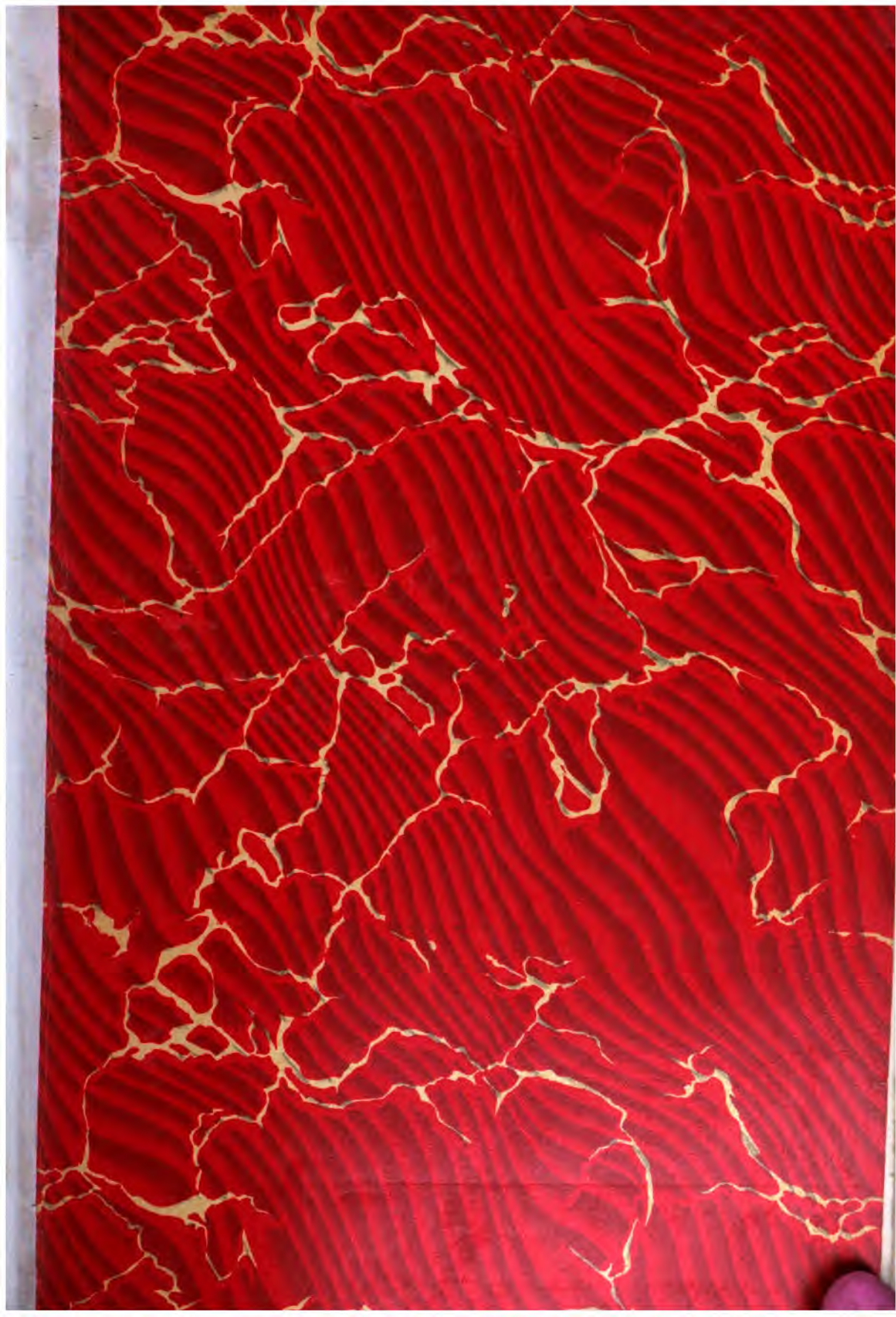
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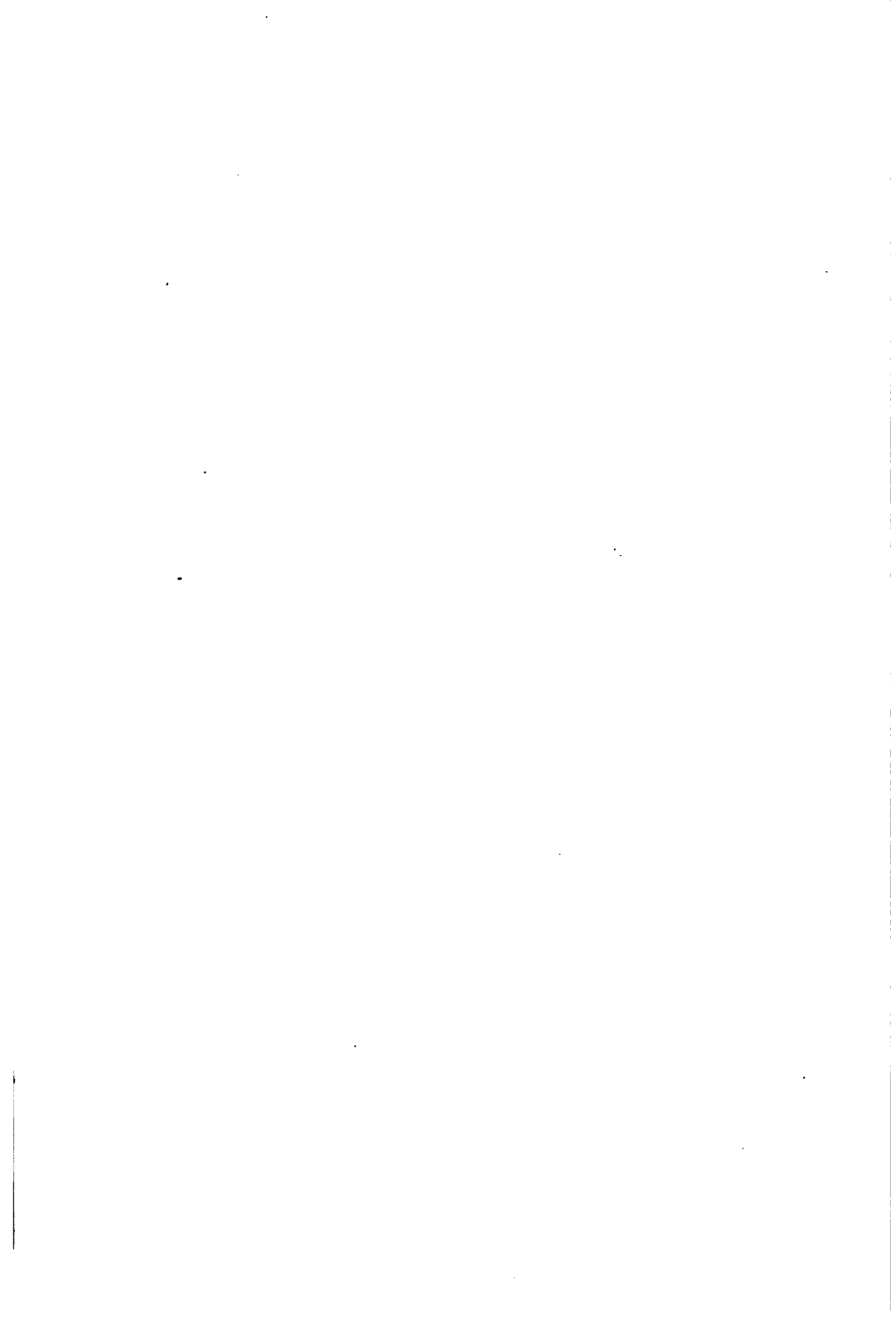
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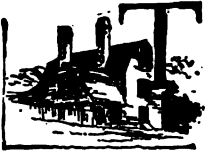
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Foreword



THE steady growth and development of the Building Industry, as illustrated in the increased size and complexity of buildings, has created a demand for better constructive methods. New methods, new tools, and labor-saving ideas have been evolved as new problems of construction have presented themselves, but the excellent material dealing with special phases is so scattered that the reader, who desires to acquire anything in the way of a builder's library, has found himself confronted with serious difficulties. He has been obliged to a great extent to make his selection blindly, resulting in much duplication of material without securing needed information on many important points.

¶ In the belief that there is a demand for a library which shall embrace the best practice of Contractors, Carpenters, and Builders, these volumes have been prepared. The aim has been not merely to create a work which will appeal to the trained expert, but one that will commend itself to the beginner and to the self-taught, practical man by giving him a working knowledge not only of the principles of his trade, but also of the best labor-saving devices and short-cut methods by which he can make his time count for more to his employer and to himself.

¶ The work will be found to cover many important topics on which little information has heretofore been available. This is especially apparent in such sections as those on The Steel

Square; Stair-Building; Estimating; Building Superintendence; Contracts and Specifications, including the principles and methods of awarding and executing government contracts; Accounting for Contractors; and Building Law.

¶ The method adopted in the preparation of this Cyclopedia is that which the American School of Correspondence has developed and employed so successfully for many years. This method is not an experiment, but has stood the severest of all tests, that of practical use, which has demonstrated it to be the best devised for the education of the busy workingman.

¶ The various sections have been prepared especially for home study, each written by an acknowledged authority on the subject. The arrangement of matter is such as to carry the reader forward by easy stages. Series of Review Questions are inserted in each volume, enabling the reader to test his knowledge and make it a permanent possession. The illustrations have been selected with unusual care to elucidate the text. Editors and writers have been selected because of their familiarity with, and experience in handling, the various subjects. Writers with practical experience have been given preference over those with only theoretical training, and practicability has been considered of greater importance than literary excellence.

¶ In conclusion, grateful acknowledgment is made to the authors and collaborators, to whose hearty co-operation is due whatever excellence this work may possess.

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CARPENTRY.

PART I.

The art of Carpentry has been practiced by men in all ages and in all lands, and is likely to continue as long as there is any timber out of which dwellings and utensils can be made. Under different conditions and in widely separated parts of the world there have been developed various methods of doing the same work, and men have attained to various degrees of proficiency in the handling of tools, and in the making of the tools themselves. From the time when the primitive man built himself a hut out of brush-wood and mud, to the present day, when we live in comfortable dwellings built of seasoned timber, there has been constant progress and development, so that there has accumulated a vast amount of experience to which we are the fortunate heirs.

The carpenter has always found his material at hand, provided by nature, and needing only to be cut down and shaped to suit his purposes. In those places where wood did not grow near by, there were no carpenters; but instead, workers in stone or clay.

A knowledge of the characteristics of wood, which plays so important a part in all our lives and which is so plentiful in our own land, is likely to prove of advantage to anyone, and is an absolute necessity to a carpenter. Let us therefore, first of all, devote some space to a consideration of timber, both in its natural state, and in its commercial form as prepared for the market.

NATURAL TIMBER.

Wood is one of the most common of building materials, and may be seen everywhere in its natural state as well as in various forms prepared for use. It is all taken originally from some kind of tree or shrub, and a consideration of the manner of growth of the tree itself will explain many peculiarities and defects of timber in its commercial form.

Classes of Trees. The trees from which most of our timber is taken are of two kinds: the "broad-leaved," such as the oak, poplar, and maple, and the "conifer" or "needle-leaved," such as the pines, the fir, and the cedar. In the South some timber is used which comes from another class of trees, of which the palms are the most common representatives; the use of this timber, however, is very limited. In general, it may be said that the wood from the broad-leaved trees is "hardwood" while that from the conifers is "softwood," but this rule does not hold true in all cases.

Manner of Growth. There is a marked difference between the three classes of trees mentioned above in regard to their manner of growth. While the members of the third class, the palms and others, grow only at the top, and have the same diameter of trunk after years of development, the members of the other two classes in-

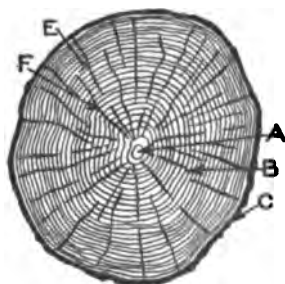


Fig. 1. Section of Log.

crease in size of trunk as well as in height. Each year a new layer of wood is formed on the outside of the trunk and branches, underneath the bark, and the age of the tree may usually be determined by counting the number of layers. In the center of the tree there is always a small whitish part, called the "pith," about which the wood itself is arranged in concentric rings, as shown in Fig. 1, in which A is the pith, B the woody part of the tree, and C the bark. The arrangement of the wood in concentric rings is due to the fact that it was formed gradually, one layer being added each year, and for this reason the rings or layers are called "annual rings."

The wood nearest the center, or pith, is considerably harder and darker in color than that which is on the outside nearer the bark; it is called the "heartwood" to distinguish it from the other which is called the "sapwood." Only the heartwood should be used for building work. The reason why it is harder than the sapwood is that it is older and has been compressed more and more each year as the tree has increased in size, and the pores have gradually become filled up. The sapwood is soft and of lighter color and shows that it has been recently formed. The time required to transform the wood from sapwood into heartwood varies from nine to thirty-five

years, according to the nature of the tree, and those trees which perform this hardening in the shortest time are usually the most durable. The sap rises in the spring from the roots of the tree to the branches and twigs, forming the leaves, and in the autumn it flows back again between the wood and the bark. Thus a new annual ring is formed.

The width of the annual rings varies from $\frac{1}{50}$ inch to $\frac{1}{8}$ inch according to the character of the tree and the position of the ring. In general it may be said that the widest rings are found nearest the center, or pith, and that they grow regularly narrower as they approach the bark. Also they are wider at the bottom of the trunk than at the top. The rings are very seldom circular or regular in form, but follow the contour of the tree trunk.

In addition to the annual rings there may be seen on the cross-section of any log other lines which run from the center toward the bark at right angles to the annual rings. These are called the "medullary" rays. Usually they do not extend to

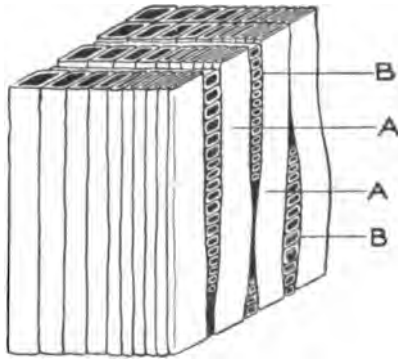


Fig. 2. Arrangement of Fibers.

the bark, but alternate with others which start at the bark and run inward toward the center but are lost before they reach the pith. This is shown at E and F in Fig. 1.

Details of Structure. The two above-mentioned classes of wood differ considerably in their structure, that of the conifers being very simple and regular in arrangement, while that of the broad-leaved trees is complex and irregular. The wood is made up of bundles of fibers or long tubes, parallel to the stem of the tree, which are crossed by other fibers that form the medullary rays, passing from the pith to the bark and binding the whole together. Besides these there are resin ducts and other fibers scattered through the trunk of the tree. The arrangement is shown in Fig. 2. A A are the long fibers, and B B the pith or medullary fibers. Of course these are so small that the individual fibers cannot be distinguished without the aid of a powerful microscope. In pine more than fifteen thousand pith rays occur on a square inch of section.

Grain of Wood. Woods are commonly spoken of as "fine-grained," "coarse-grained," "cross-grained," or "straight-grained." The wood is said to be fine-grained when the annual rings are relatively narrow, and coarse-grained when these rings are wide. Fine-grained wood can be made to take a high polish while with coarse-grained wood, in general, this is not possible. When the

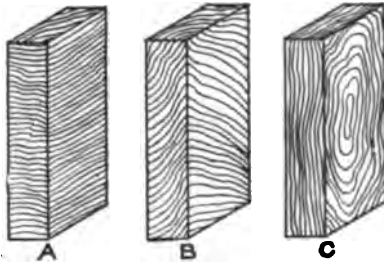


Fig. 3. Grain of Wood.

fibers are straight, and parallel to the direction of the trunk of the tree, the wood is said to be straight-grained, but if they are distorted or if they are twisted so as to be spiral in form, not growing straight up but following around the trunk of the tree, the wood is said to be cross-grained.

In Fig. 3 are shown three pieces of timber of which A is absolutely cross-grained, B is partially cross-grained and C is straight-grained.

Defects. Most of the defects which render timber unsuitable for building are due to irregularities in the growth of the tree from which the timber was taken. These defects are known by various names, such as "Heartshakes," "Windshakes," "Starshakes," and "Knots." Other defects are due to deterioration of the timber after it has been in place for some time or even before the tree has been felled, among which are "Dry Rot" and "Wet Rot." The defects of the first class are defects of structure — those of the second class are defects of the material itself.



Fig. 4. Heartshake.

Heartshake. Fig. 4 shows what is known as a heartshake. There is first a small cavity at the heart of the tree caused by decay, and flaws or cracks extend from it out toward the bark. The heartshake is most often found in those trees which are old, rather than in young, vigorous saplings; it is especially to be feared in hemlock timber.

Windshake. Fig. 5 shows what is known as a windshake or cupshake. This is caused by a separation of the annual rings one from another so that a crack is formed in the body of the tree; this

crack may extend for a considerable distance up the trunk. This defect is said to be caused by the expansion of the sapwood, and it is also claimed that it is caused by the wrenching to which the tree is subjected by high winds. Windshakes are very often found in pine timber.

A *starshake* is very much like a heartshake, the chief difference being that the starshake cracks extend right across the center of the trunk without any appearance of decay at that point.

Dry rot in timber is caused by a fungus growth, and takes place most readily when the timber is in such a position that it is alternately wet and dry. If wood is kept perfectly dry, or, on the other hand, is kept constantly under water, it will last indefinitely without any sign of rot. For this reason piles should always be cut off below the water level. Decay takes place very rapidly when the wood is in a confined position, as when

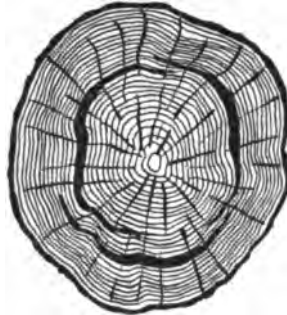


Fig. 5. Windshake.

buried in a brick wall, so that the gases cannot escape. It is also hastened by warmth, and is much more common in the South than in the northern states. Decay may be prevented by introducing into the timber certain salts, such as the salts of mercury. It may also be prevented by heating the wood to a temperature above 150 degrees Fahrenheit and maintaining that temperature. All wood should be perfectly seasoned before being painted, and good ventilation should always be provided for. Wood should be especially protected whenever in contact with masonry from which it may absorb moisture.

Wet rot is a form of decay which takes place in the growing tree. It is caused by the tree becoming saturated with water, as in a swamp or bog, and it may be communicated from one piece of timber to another by contact.

Warping in timber is the result of the evaporation or drying out of the water which is held in the cell walls of the wood in its natural state, and the consequent shrinkage of the piece. If timber were perfectly regular in structure, so that the shrinkage would be the same in every part, there would be no warping; but wood is made up of a large number of fibers, the walls of which are of differ-

ent thickness in different parts of the tree or log, so that in drying one part shrinks much more than another. Since the wood is rigid, one part cannot shrink or swell without changing the shape of the whole piece, because the block as a whole must adjust itself to the new conditions; consequently the timber warps.

In Fig. 6, if the fibers in the top portion of the piece near the face $a b e$ happen to have, on the average, thicker walls than those

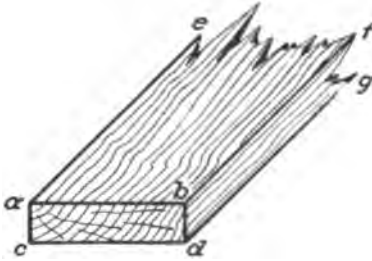


Fig. 6.

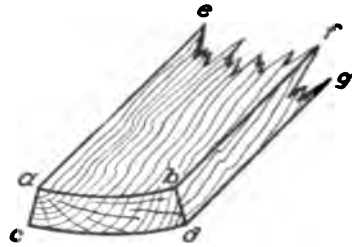


Fig. 7.

in the bottom portion, near the face $c d g$, the top part will shrink more than the bottom; the distance $a b$, originally equal to the distance $c d$, becomes smaller and the shape of the whole piece changes, as shown in Fig. 7.

The only way in which warping can be prevented is to have the timber thoroughly dried out before it is used. After it is once thoroughly seasoned it will not warp unless it is allowed to absorb more moisture. All wood that is to be used for fine work, where any warping after it is in place will spoil the appearance of the whole job, must be so seasoned, either in the open air or in a specially prepared kiln.

The wood of the "conifers," which is very regular in its structure, shrinks more evenly and warps less than the wood of the broad-leaved trees with its more complex and irregular structure. Sapwood, also, as a rule shrinks more than does heartwood.

Checks also are due to the uneven shrinkage of timber. In any log there is a chance for the wood to shrink in two directions — along the radial lines following the direction of the medullary rays, and around the circumference of the log, following the direction of the annual rings. If the wood shrinks in both directions at the same rate, the only result will be a decrease in the volume of the log, but if it shrinks more rapidly in one of these directions than it does in

the other, the log must crack around the outside as shown in Fig. 8. This cracking is called "checking," and is likely to take place. In

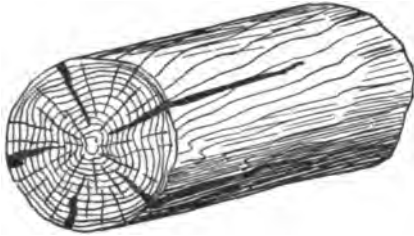


Fig. 8. Cracks Caused by Shrinkage.

timber which has been prepared for the market it shows itself in the form of cracks which extend along the faces of solid square timbers and boards, and seriously impairs the strength. Fig. 9 shows checks in a square post or column.

Knots are very common in all timber. They are formed at the junction of the main tree trunk and a branch or limb. At such points the fibers in the main trunk, near the place where the branch comes in, do not follow straight along up the trunk, but are turned aside and follow along the branch as shown in Fig. 10. Frequently a branch may be broken off near the trunk while the tree is still young, and the tree continue to grow. The trunk will increase in size until the end of the branch, which was left behind buried in the main trunk, is entirely covered up. Meanwhile the end of the branch dies and a knot is formed. This bit of dead wood has no connection with the living wood about it. In time it works loose, and when the tree is sawed up into boards the knot may drop out. A

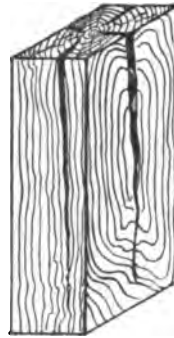


Fig. 9. Checks in Square Post.



Fig. 10. Knots.

knot does not seriously impair a piece subjected to a compressive stress, so long as it remains in place, but it greatly weakens a piece subjected to tension. A knot always spoils the appearance of any wood which is to be polished.

TIMBER IN ITS COMMERCIAL FORM.

Conversion of Timber. Timber may be found in lumber yards in certain shapes ready for use, having been cut from the logs and relieved of the outside covering, or bark. There are various methods of cutting up the logs to form boards, planks and heavy timbers. If the log is to be squared off to form but

one heavy beam, a good rule to follow is to divide the diameter into three equal parts, and draw perpendiculars to the diameter at these points, one on each side of the diameter, as shown at A and B in Fig. 11. The points *c* and *d* in which these perpendiculars cut the circumference of the tree trunk,

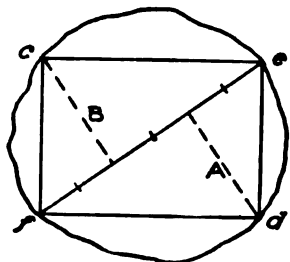


Fig. 11. Squaring off a Log.

together with the points *e* and *f* in which the chosen diameter cuts the circumference of the tree trunk, will be the four corners of the timber. The lines joining these points will give an outline of the timber. This will be found to be the largest and best timber which can be cut from the log.

Another good rule is to divide the diameter of the log into *four* equal parts and proceed in the same way as described above, using the outside quarter points on the diameter as shown in Fig. 12. This method will give a stiffer beam but it will not be so strong.

In Fig. 13 are shown several different methods of cutting planks from a log. First it is divided into quarters, and the planks are cut out as shown. The method shown at A, called "quarter sawing," is the best. All the planks are cut radiating from the center and there will be no splitting and warping. A fairly good method is that shown at B, where the planks are pretty nearly in radial lines and may be much more easily cut out than can those shown at A. The method shown at C is a common one and leads to fairly good results, although only the plank in the center is on a radial line. It is practically as good a method as that shown at B and is much more simple. The method shown at D is not so good as the others; planks cut in this way being very liable to warp and twist. If the silver grain, caused by the cutting of the medullary rays, is desired, the planks should be cut as at A or B.

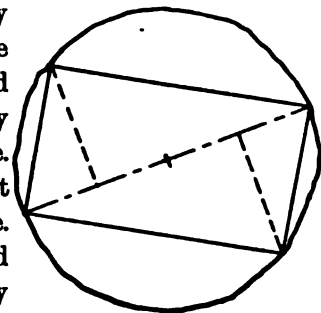


Fig. 12. Squaring off a Log.

Planks may sometimes be simply sliced from the log as shown in Fig. 14, without first dividing it into quarters. This is the worst possible way to cut them, as the natural tendency of the timber to

shrink causes the planks to curl up as shown in Fig. 15. It is almost impossible to flatten them out again and they cannot be used as they are.

VARIETIES OF TIMBER.

There are a great many different kinds of timber growing in the United States, and a considerable quantity is imported from other countries. Each variety possesses certain characteristics which render it especially suitable for use in one part of the build-

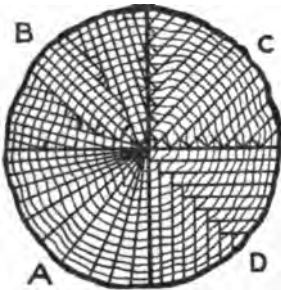


Fig. 13. Quarter Sawing.

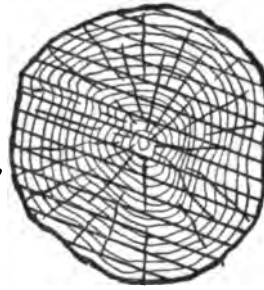


Fig. 14. Straight Sawing.

ing, while the same peculiarities of growth or of texture may unfit it for use in another place.

For timbers which are to be partly buried in the ground a wood is required which is able to withstand the deteriorating effects of contact with the earth; and for this purpose chestnut, white cedar, cypress, redwood or locust may be used.

For light framing we need a cheap, light wood free from structural defects such as knots and shakes, and which can be obtained in fairly long, straight pieces. Spruce, yellow pine, white pine and hemlock all satisfy these requirements fairly well, spruce being perhaps a little better than the others, and at any rate more popular.

For heavy framing, such as wooden trusses, girders and posts, we require a strong timber and one which can be obtained in large, long pieces. Georgia pine, Oregon pine and white oak may all be used for such work, and also Norway pine and Canadian red pine.



Fig. 15.

A wood which is easily worked and which will also withstand the effects of the weather is needed for the outside finish; for this we select white pine and

also cypress and redwood. The same woods are used for shingles, clapboards and siding, with the addition of cedar for shingles, and sometimes Oregon pine and spruce for siding.

For the interior finish is chosen a wood which will make a pleasing appearance, and which will take a polish; while for floors, hardness and resistance to wear are the further requirements. For floors, oak, hard pine, and maple are good; and for the rest of the interior finish, white pine, cypress and redwood, or any of the hard woods such as ash, butternut, cherry and mahogany, may be selected.

Some of the more important varieties of timber used in carpentry will now be mentioned, and a brief description of each kind given to convey an idea of its characteristics and the part of the country from which it comes.

EVERGREENS OR CONIFERS.

Cedar. There are five different kinds of white cedar in the United States, of which four are different species of the white cedar, and the fifth is what is known as "canoe" cedar. The wood is not very strong, but is light and soft, possessing considerable stiffness and a fine texture. In color it is grayish brown, the sapwood being, however, of a lighter shade than the heartwood. It seasons quickly, is very durable and does not shrink or check to any great extent. Its principal use in carpentry is for shingles, for which its durability makes it especially valuable, and for posts and ties. The trees are usually scattered among others of different kinds, forming occasionally, however, quite considerable forests. They are found all through the northern part of the country and on the Pacific coast in California, Oregon and Washington. Some of the trees are of medium size while others are very large, especially the canoe cedar in the Northwest.

In addition to the white cedars, there are the red cedars, which are similar to the others, but have a somewhat finer texture. There are two varieties, the red cedar and redwood, the former found principally in the southern states and the latter only in California. Red cedar is used but little in building construction except for cabinet work and veneers, but redwood has been used extensively in the West for outside finish, shingles and clapboards. Its resistance to

fire is remarkable, which makes it valuable for the exterior of dwellings, but it is too soft for interior finish.

Cypress. This wood is found in the southern states only, where it grows in the swamp land along the banks of the rivers. Although there are a great many varieties, they are similar in their general characteristics and differ only in quality. "Gulf cypress," growing near the Gulf of Mexico, is the best. The timber is light, straight-grained and soft, and is used for shingles and siding, water tables, sills and gutters. It does not warp and shows great resistance to dampness.

Hemlock. There are two varieties of hemlock, one found in the northern states, from Maine to Minnesota, and also along the Alleghanies, southward to Georgia and Alabama; and the other found in the West, from Washington to California, and eastward to Montana. The eastern tree is smaller than the western, and its wood is lighter and softer and generally inferior. The timber is of a light reddish-gray color, fairly durable, but shrinks and checks badly, and is rough, brittle, and usually cross-grained. It is sometimes used in the East for cheap framing, but it is so liable to imperfections such as windshakes and starshakes that it is not suitable for this purpose. It is often used for rough boarding or sheathing.

Spruce. There are three kinds of spruce — white, black, and red, of which the white spruce is the variety commonly found on the market. The wood is light and soft, but fairly strong, and is of a whitish color. It is much used in the northeastern states for light framing, but can be obtained only in small sizes. It is considered by many to be the best framing timber, excepting the pines.

The white spruce is found scattered throughout all of the northern states, along the streams and lakes, the largest varieties being in Montana.

The black spruce is found in Canada and in some of the northern states. It is distinguished from the other varieties only by its leaves and bark.

The red spruce is sometimes known as Newfoundland red pine and is found in the northeastern part of North America. Its wood is similar to the black spruce.

Pines. There are two distinct classes of pines used in building work, the soft and the hard pines, both of which are found in great

abundance scattered over the whole of the United States. The great variety of uses to which pine timber may be applied in building construction and the ease with which it can be cut and shipped to market, make it the most popular wood in use at the present time. The softer varieties are used for outside finishing of all sorts, and the harder kinds for heavy framing and for flooring. The tree itself is very tall, with a straight trunk and few branches, so that timbers can be obtained in large sizes and great lengths. There are many different kinds of pines, which are recognized in various parts of the country under various names, but there are five general classes into which the species is commonly divided, though the same timber may be called by different names in two different localities, as will be seen.

1. The term "hard pine" is used to designate any pine which is not white pine, and is a very general classification, though it is often met with in specifications and in works on Carpentry.

2. "White pine," "soft pine" and "pumpkin pine" are terms which are used in the eastern states for the timber from the white pine tree, while on the Pacific coast the same terms refer to the wood of the sugar pine.

3. The name "yellow pine" when used in the northeastern part of the country applies almost always to the pitch pine or to one of the southern pines, but in the West it refers to the bull pine.

4. "Georgia pine" or "longleaf yellow pine" is a term used to distinguish the southern hard pine which grows in the coast region from North Carolina to Texas, and which furnishes the strongest pine lumber on the market.

5. "Pitch pine" may refer to any of the southern pines, or to pitch pine proper, which is found along the coast from New York to Georgia and among the mountains of Kentucky.

Of the soft pines there are two kinds, the white pine and the sugar pine, the latter being a western tree found in Oregon and California, while the former is found in all the northern states from Maine to Minnesota. There is also a smaller species of white pine found along the Rocky Mountain slopes from Montana to New Mexico.

There are ten different varieties of hard pine, of which, however, only five are of practical importance in the building industry. These are the "longleaf southern pine," the "shortleaf southern pine," the "yellow pine," the "loblolly pine" and the "Norway pine."

The longleaf pine, also known as the "Georgia pine," the "yellow pine" and the "long straw pine," is a large tree, which forms extensive forests in the coast region from North Carolina to Texas. It yields very hard, strong timber which can be obtained in long, straight pieces of very large size.

The loblolly pine is also a large tree, but has more sapwood than the longleaf pine, and is coarser, lighter and softer. It is the common lumber pine from Virginia to South Carolina, and is also found in Texas and Arkansas. It is known as well by the name of "slash pine," "old field pine," "rosemary pine," "sap pine," and "short straw pine," and in the West as the Texas pine.

The shortleaf pine is much like the loblolly pine and is the chief lumber tree of Missouri and Arkansas. It is also found in North Carolina and Texas.

The Norway pine is a northern tree found in Canada and the northern states. It never forms forests, but is scattered among other trees, and sometimes forms small groves. The wood is fine-grained and of a white color, but is largely sapwood and is not durable.

BROAD-LEAVED TREES.

Ash is a wood that is frequently employed for interior finishing in public buildings, such as schoolhouses, and in the cheaper classes of dwelling houses. It is one of the cheapest of the hard woods; it is strong, straight-grained and tough, but is coarse in texture. It shrinks moderately, seasons with little injury, and will take a good polish. The trees do not grow together in forests, but are scattered. They grow rapidly, and attain only medium height. Of the six different species found in the United States, only two, the "white ash" and the "black ash," are used extensively in building work. The first is more common in the basin of the Ohio River, but is also found in the North from Maine to Minnesota, and in the South, in Texas. The black ash is found from Maine to Minnesota, and southward to Virginia and Arkansas. There is very little difference between the two species. The black ash is also known as the "hoop ash" and the "ground ash."

Beech. Another wood used to some extent for inside finish is the beech. It is heavy, hard and strong, but of coarse texture like the ash. In color it is light brown, or white. It shrinks and checks

during the process of drying and is not durable when placed in contact with the ground. It works easily, stands well, and takes a good polish.

Birch is a very handsome wood of a brown color and with a satiny luster. It takes a good polish, works easily, and does not warp after it is in place, but it is not durable if exposed. It is used quite extensively for inside finish, and to imitate cherry and mahogany, as it has a grain which is very similar to the grain of these woods. The trees are of medium size and form large forests. They are found throughout the eastern part of the United States.

Butternut is also used as a finishing wood, and is cheaper than many of the other harder woods. It is light, but not strong, and is fairly soft. In color it is light brown. The trees, of medium size, are found in the eastern states from Maine to Georgia.

Cherry is a wood which is frequently used as a finishing wood for the interior of dwellings and of cars and steamers; but owing to the fact that it can be obtained only in narrow boards, it is most suitable for moulded work, and work which is much cut up. The wood is heavy, hard, strong and of fine texture. The heartwood is of a reddish brown color, while the sapwood is yellowish white. It is very handsome and takes a good polish, works easily and stands well. It shrinks considerably in drying. The timber is cut from the wild black cherry tree, which is of medium size and found scattered among the other broad-leaved trees along the western slope of the Alleghanies and as far west as Texas.

Chestnut timber is used in cabinet work, for interior finishing, and sometimes for heavy construction. It is light, fairly soft, but not strong. It has a rather coarse texture, works easily and stands well, but shrinks and checks in drying. The timber is very durable. The tree grows in the region of the Alleghanies, from Maine to Michigan, and southward to Alabama.

Elm. There are five species of elm trees in the United States, scattered throughout the eastern and central states. The trees are usually large and of rapid growth, and do not form forests. The timber is hard and tough, frequently cross-grained, hard to work, and shrinks and checks in drying. The wood has not been used very extensively in building, but has a beautiful figured grain, can take a high polish, and is well adapted to staining. The texture is coarse to fine, and the color is brown with shades of gray and red.

Gum. The wood of the gum tree is used extensively for cabinet work, furniture, and interior finish. It is of fine texture and handsome appearance, heavy, quite soft, yet strong, and reddish brown in color. It warps and checks badly, is not durable if exposed, and is hard to work. The species of gum tree used in carpentry is the sweet gum, which is of medium size, with straight trunk; it does not form forests, though it is quite abundant east of the Mississippi River.

Maple. Almost all of the maple used in building work comes from the sugar maple tree, which is most abundant in the region of the Great Lakes, but which is also found from Maine to Minnesota, and southward to Florida. The trees are of medium to large size, and form quite considerable forests. The wood is heavy and strong, of fine texture, and often has a fine wavy grain which gives the effect known as "curly." It is of a creamy white color, shrinks moderately, works easily and takes a good polish. It is often used for flooring, and sometimes for other inside finish.

Oak. There are about twenty different kinds of oak to be found in various parts of the United States, but there are three distinctly different species, which are sold separately. These are the "white oak," the "red oak" and the "live oak." The red oak is usually more porous, less durable and of coarser texture than the white oak or the live oak. The trees are of medium size and form a large proportion of all the broad-leaved forests. Live oak was once extensively used, but has become scarce and is now expensive. Both the red oak and the white oak are used for inside finishing, but they are liable to shrink and crack and must therefore be thoroughly seasoned. They are of slightly different color, the white oak having a straw color while the red oak has a reddish tinge, so that they cannot be used together where the work is to be finished by polishing. Oak is always better if quarter-sawed, when it shows what is known as the "silver grain."

Poplar. This wood is also known as "whitewood" and "tulip wood." There are a number of different varieties growing in various parts of the country. The tree is large, and is most common in the Ohio Basin, but does not form forests. The wood is light, soft, free from knots, and of fine texture. In color it is white, or yellowish-white, and frequently it has a satiny luster. It can be so finished as to retain its natural appearance, but it is often stained to imitate

some of the more costly woods, such as cherry. It is used extensively for cheap inside finish and fittings, such as shelving, and sometimes for doors, but it warps badly if it is not thoroughly seasoned.

Sycamore is frequently used for finishing, and is a very handsome wood. It is heavy, hard, strong, of coarse texture, and is usually cross-grained. It is hard to work, and shrinks, warps, and checks considerably. The tree is of large size and rapid growth, found in all parts of the eastern United States, but is most common along the Ohio and Mississippi Rivers.

Black Walnut is a wood which has been and is still used very extensively for interior finishing and in the manufacture of furniture. It is a heavy, hard timber, of coarse texture, and of a dark-brown color. Very handsome pieces having a beautiful figure, may be selected for veneers for furniture and cabinet work. Although the wood shrinks somewhat in drying, it works easily, stands well, and will take a very good polish. The tree is large and of rapid growth. It was formerly very abundant in the Alleghany region, and was found from New England to Texas and from Michigan to Florida, but it is now becoming scarcer and the timber is expensive.

Imported Timber. Besides the woods which grow in the United States, a number of others are brought in from foreign lands for use in the best grade of public buildings and private residences. The most popular of these are the mahogany, rosewood, satinwood, French burl, and Circassian walnut.

Mahogany comes from Cuba and Mexico, and formerly was obtained also from Santo Domingo and Honduras. It is generally imported in the rough log and cut up by the purchasers as it is required. The wood is easy to work, will take an excellent polish, and stays in place very well if it is well seasoned. It varies in color from very light to deep red and becomes darker with age. It is usually employed in the form of veneers on account of its cost.

Satinwood comes from the West Indies, French burl from Persia, and Circassian walnut from near the Black Sea. They are all very expensive and are used only as veneers, and in only the finest work.

GENERAL CHARACTERISTICS OF TIMBER.

In speaking of wood we are accustomed to use certain words to express our idea of its mechanical properties, or of its probable



**FRONT AND REAR VIEWS OF RESIDENCE OF MRS. H. M. COBB, MAGNOLIA DRIVE,
CLEVELAND, OHIO**

Watterson & Schneider, Architects, Cleveland, Ohio.



behavior under certain conditions. Thus we say that a wood is hard, or tough, or brittle, or flexible, and frequently we use these terms without having a clear understanding of just what they mean. A very brief discussion of some of these properties or characteristics of timber will now be given in order that we may see what peculiarities of structure or of growth cause them.

Hardness. If a block of wood is struck with a hammer when lying on a bench, the hammer-head will make an impression or dent in the wood, which will be deeper or shallower according as the wood is soft or hard. A wood is said to be very hard when it requires a pressure of about 3,000 pounds per square inch to make an impression one-twentieth of an inch deep. A hard wood requires only about 2,500 pounds to produce the same effect. Fairly hard wood will be indented by a pressure of 1,500 pounds, and soft woods require even less. Maple, oak, elm and hickory are very hard; ash, cherry, birch and walnut are hard; the best qualities of pine and spruce are fairly hard; and hemlock, poplar, redwood and butternut are soft.

Toughness. "Toughness" is a word which is often used in relation to timber, and implies both strength and pliability, such as is found in the wood of the elm and hickory. Such timber will withstand the effect of jars and shocks which would cause other woods, like pine, to be shattered.

Flexibility. Timber is said to be flexible when it bends before breaking instead of breaking off short, or, in other words, a flexible wood is the opposite of one which is brittle. The harder woods, taken from the broad-leaved trees, are usually more flexible than the softer woods, taken from the cone-bearing trees. The wood of the main tree trunk is more flexible than that of the limbs and branches, and moist timber is more flexible than dry wood. Hickory is one of the most flexible woods.

Cleavage. Most woods split very easily along the grain, especially when the arrangement of the fibers is simple, as in the conifers. In splitting with an axe, the axe-head acts as a wedge and forces the fibers apart, and usually the split runs along some distance ahead of the axe. Hard woods do not split so easily as soft woods, and seasoned wood not so easily as green wood, while all timber splits most easily along radial lines.

THE STEEL SQUARE.

If it is important that a workman should know his material thoroughly, it is even more essential that he should understand his tools and be able to apply them in the most useful way to any particular piece of work. This is especially true of the tool known as the "Carpenter's Steel Square" which is without doubt the most useful of all the tools to be found in a carpenter's chest, but which is not always thoroughly understood even by experienced workmen. As the square will be referred to frequently in these pages a brief description of it will be given.

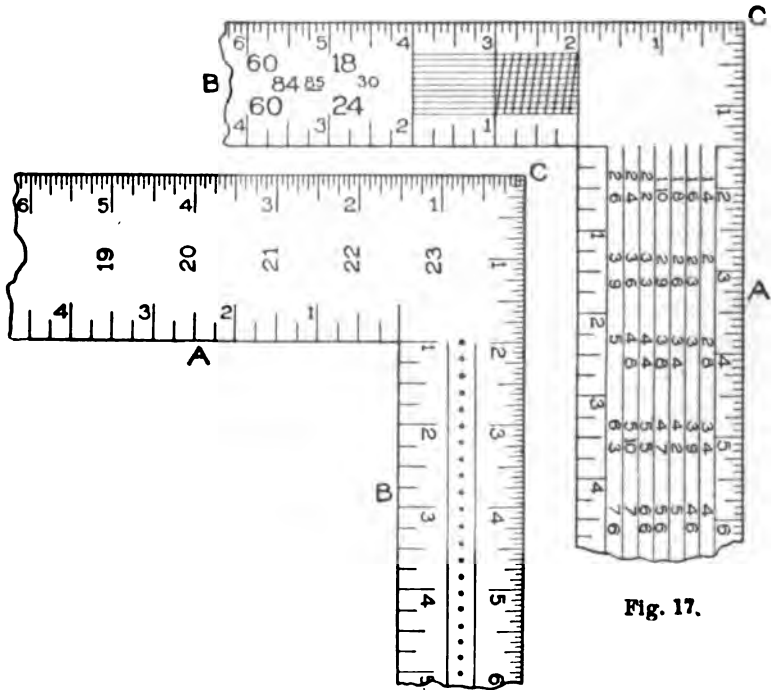


Fig. 16. Carpenter's Steel Square.

It is shown in Figs. 16 and 17, each view showing one side of the square. It is essentially a measuring and calculating tool, and all of the various markings and scales found on either side have their own special uses. All squares are not alike, there being several kinds on the market and in daily use among mechanics, but the

variations in the markings on the different squares are so slight that if one is explained the others can be readily understood.

There are three parts to the tool which are distinguished by special names, the tongue, the blade and the heel. The longer, wider arm is called the blade; the shorter, narrower arm is called the tongue; and the point in which the tongue and the blade meet, on the outside edge of the square, is called the heel. In the figures, A is the blade, B the tongue, and C the heel. In carefully made tools, the blade is two feet long and two inches wide, while the tongue is from fourteen to eighteen inches long and one and one-half inches wide.

Starting at the heel and reading away from it, the outside edges of the blade and the tongue on both sides of the square, are divided into inches and fractions of an inch, one side of the square showing sixteenths and the other side showing twelfths. Starting at the interior angle opposite the heel, the inside edges are divided in a similar way except that the inches on both sides of the square are divided into eighths only. In some squares one of these scales is shown divided into thirty-seconds of an inch. On one side of the blade the inch marks are numbered in both directions, from the heel outward, and also from the end of the blade inward, toward the heel, so that each inch mark has two numbers, one showing its distance, in inches, from the heel, and the other showing its distance from the end of the blade. These extra numbers are very useful in measuring the depth of mortises and in all similar work. The arrangement is shown in Fig. 16.

On the other side of the blade, which is shown in Fig. 17, in addition to the scales on the two edges, we find a column of figures directly under each of the inch marks on the outer edge. The figures are arranged in eight rows, parallel to the edges of the square, and the rows are marked off by lines running the full length of the blade. These figures enable a man to tell at a glance the number of board-feet in a piece of timber whose dimensions he knows. Under the twelve-inch mark there are figures showing the different lengths which can be measured in this way, so that each row of figures corresponds to a certain length, found under the twelve-inch mark. Under each of the other inch marks there are figures, each of which gives the number of board-feet in a plank one inch thick, whose

width in inches is indicated by the number of the inch marks under which the figure is found, and whose length, in feet, is indicated by the number found in the same row with the figure itself under the twelve-inch mark. There are seven or eight different lengths given, and twenty-three different widths for each length, the widths varying from two inches up to twenty-four inches. The figures expressing the board measure are given as feet and inches, the number of feet being separated from the number of inches by a vertical line, with the feet on the left and the inches on the right. For instance, 11 8 is read as eleven feet and eight inches.

On the same side of the square which shows the board measure on the blade, we find on the tongue what is known as the "brace rule," placed in the middle of the tongue between the two scales which are marked off along the edges. The brace rule consists of two similar numbers representing length in feet, placed one above the other, with a third number placed just to the right of them, as $2\frac{1}{4}$ 33.94. The two similar numbers represent the length, in feet, of the side of a perfect square, and the third number represents the length of the diagonal of this square, expressed in feet and decimals of a foot. In other words the number to the right is equal to the square root of the sum of the squares of the other two numbers, or is equal to one of these numbers multiplied by the square root of 2, which is 1.414, in accordance with the principle that the length of the diagonal of a square is equal to the length of the side multiplied by the square root of two. There are a number of different sets of figures like this on the tongue of the square; they are very useful in finding the length of braces which make an angle of forty-five degrees with the post into which they frame, or which have a total rise equal to their total run.

On the same side of the tongue which shows the brace rule, placed near the heel of the square, is found another scale which may be called the "Scale of Hundredths." It consists of a number of lines drawn along the tongue parallel to the edges, which are just one-tenth of an inch apart.

They are drawn diagonally, so that the end of one line is directly under the starting point of the next line. By means of this scale any number of hundredths of an inch can be readily measured off. The scale may be seen in Fig. 17.

The opposite side of the square shows two lines, drawn near together in the center of the tongue. Parallel to the edges and between these lines a single line of dots is placed. They are a little more than one-fifth of an inch apart and numbered by tens. The dots constitute what is called the "octagon scale," and are used in the process of cutting a stick of octagonal section out of a stick of square section. Suppose for example we take a stick ten inches square and wish to cut from it a stick of octagonal section. We will first draw a line lengthwise in the center of each of the four faces of the square stick. Then applying the square, we measure off on both sides of this center line, in each face, perpendicular to the edges of the piece, as many of the spaces shown by the line of dots as there are inches in the side of the square stick. Thus in this case, we measure off ten spaces on each side of each center line, and then draw through the points thus located two lines in each face, parallel to the center line and equidistant from it. These eight lines represent the eight edges of the octagonal stick, and by cutting away the four corners, the desired shape is obtained.

This completes the description of the markings upon the square, and although there are undoubtedly some squares in use which may not be exactly like the model described, they all have nearly the same markings, arranged in the same way or with but slight variations.

Some of the numerous applications of the square in the solution of practical problems in Carpentry are explained in connection with the work on "framing," and others will suggest themselves to the thoughtful student. The uses to which the instrument may be put are so many and so various that it would require a large book to explain them all, but those who use the tool constantly will readily discover them and perhaps many new ones besides.

LAYING OUT.

Having now considered the material and the most important of the tools with which the carpenter performs his work, we shall pass to a consideration of the work itself, and see how a building of wooden construction is put together.

In undertaking the construction of any building, the first thing to do is to make a very thoughtful examination of the piece of ground upon which the structure is to be placed. This is very important,

since the character of the soil upon which a dwelling is located will very largely determine its sanitary condition, and will influence to a great extent the health of the occupants. Very often a difference of a few yards in the position of a building will be enough to cause the difference between a perfectly dry cellar and one which is constantly flooded with water. Water is, indeed, the one thing above all others which must be guarded against, since it is almost impossible to keep it out of a cellar which is sunk in damp ground.

At a certain distance below the surface of the earth there is always to be found what is known as "ground water." This stands always nearly at a level, so that it is not met with so near the surface of a slight knoll or other elevation as in the case of a depression. If possible, the house should be so located that the bottom of the cellar need not come below the ground-water level, and consequently it should be placed on comparatively high land. Below the surface of a hill, however, there may be a stratum of rock which will hold the rain water and prevent it from sinking at once to the ground-water level. Such a ledge of rock causes the water to collect, and then flow off in small subterranean streams, which will almost surely penetrate the walls of a cellar if it happens to be in their path.

A good way to discover the depth of the ground-water level, or the existence of rock ledges beneath the surface of the ground, is to dig a number of small, deep holes at various points of the site. These should be carried below the proposed level of the cellar bottom. A suitable location for the building may thus be chosen.

When the approximate position of the structure has been decided upon, the next step is to "stake it out." That is, the position of the corners of the building must be located and marked in some way on the ground, so that when the excavation is begun the workmen may know what are the exact boundaries of the cellar. This "staking out" should always be carefully attended to, no matter how small the building may be. In works of importance it is always best to have the work done by an engineer, but on small work it is customary for the contractor or the architect to attend to it. It is well to have at hand some instrument with which angles can be accurately measured, such as a transit; but the work can be done very satisfactorily with a tape measure and a "mason's square." This simple instrument is composed of three sticks of timber nailed together as shown in Fig.

18, to form a right-angled triangle. It is important that the tape used should be accurate, a steel tape being always preferable, and that the square should give an exact right angle. A mistake in the staking out may cause endless trouble when the erection of the building itself is begun, and it is then too late to remedy it.

There are several different lines which must be located at some time during the construction, and they may as well be settled at the start. These are: the line of excavation, which is outside of all; the face of the basement wall, inside of the excavation line; and, in the case of a masonry building, the ashlar line, which indicates the outside of the brick, or stone walls. In the case of a wooden structure only the two outside lines need be located, and often only the line of the excavation is determined at the outset.

The first thing to do is to lay out upon the ground the main rectangle of the building, after which the secondary rectangles which indicate the position of ells, bay windows, etc., may be located. Starting at any point on the lot where it is desired to place one corner of the building, a stake should be driven into the ground and a line

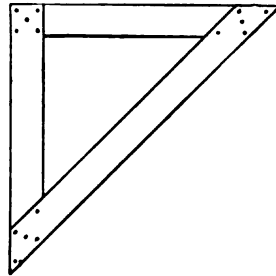


Fig. 18. Mason's Square.

laid out either parallel or perpendicular to the street upon which the structure is to face. At the end of this line, which forms one side of our rectangle, and the length of which is determined by the dimensions of the building, another stake should be driven, and these two stakes will determine the direction and the length of the line. The exact location of the ends of the line may be indicated by a nail driven into the top of each stake.

After one line has been thus laid out, others may be laid out perpendicular to it at its ends, with the aid of the mason's square and the tape measure. The accuracy of the right angle may be checked by the use of the "three-four-five" rule. This rule is based upon the fact that a triangle, whose three sides are respectively three, four, and five feet long, is an exact right-angled triangle, the right angle being always the angle between the three-foot and the four-foot sides. This fact may be proven by applying the well-known theorem which states that the length of the hypotenuse of

a right-angled triangle is equal to the square root of the sum of the squares of the other two sides. The rule may be used as follows :

Lay off on one of the side lines already laid out on the ground,

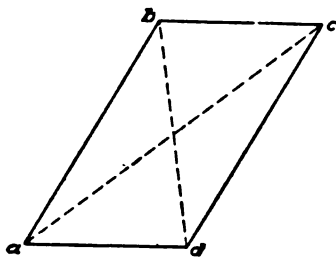


Fig. 19.

any multiple of three feet, as nine feet, or twelve feet. On the other line, presumably at right angles to the first one, lay off the same multiple of four feet, as twelve feet, or sixteen feet. Now a straight line, measured between the points so obtained, should have a length equal to the same multiple of five feet, as fifteen feet or twenty feet.

If this is not found to be the case, the angle laid out is not an exact right angle, and instead of a rectangle we have a parallelogram as shown in Fig. 19. This will not do at all, and the inaccuracy must be corrected.

It is possible to lay out the right angle in the first place by this same method, using two flexible cords, respectively four feet and five feet long. The end of the four-foot cord should be fastened at the end of the side line of the building, and the end of the five-foot cord should be fastened on this same side line, three feet away from the corner. When the loose ends of both cords are held together, and the cords are both

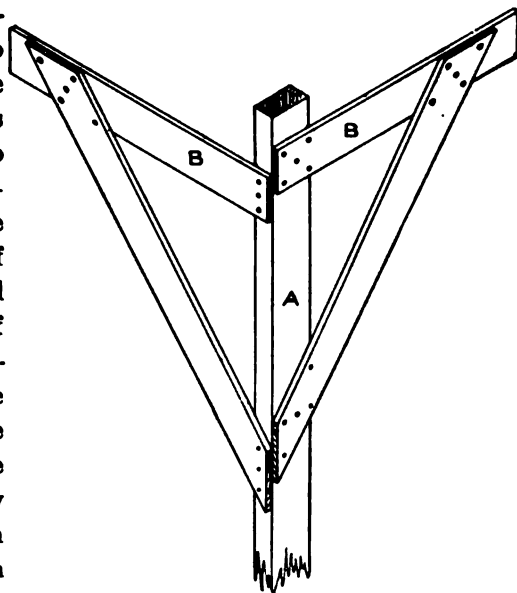


Fig. 20. Position of Corner.

drawn taut, the point where the ends meet will be a point on the side line of the building perpendicular to the first side line. It is evident that this point must be just four feet from the corner, and that the distance between it and the point on the other side line, three feet from the corner, must be five feet.

After all the corners of the building have been located, their position should be indicated by the use of "batter boards." One of these is shown in Fig. 20. It will be seen that it consists of a post A, which is set up at the corner, together with two horizontal pieces B, B, which extend outward for a short distance along the sides of the rectangle that has been laid out. The horizontal pieces may be braced securely as shown, and the whole will be a permanent indication of the position of the corner. Notches may be cut in the top of the horizontal pieces to indicate the position of the various lines, and cords may then be stretched between the notches from batter board to batter board. These cords will give the exact location of the lines.

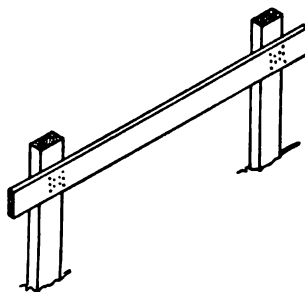


Fig. 21. Batter Boards.

Another way to indicate the position of the lines is by driving small nails into the tops of the batter boards instead of cutting notches in them; but nails may be withdrawn, while the notches, when they are once cut, cannot easily be obliterated.

Batter boards should always be set up very securely, so that they will not be displaced during the building operations. If there is danger that the form of batter board shown in Fig. 20 may be displaced, because of the large size of the structure and the length of time during which they must be used, the form shown in Fig. 21 may be substituted. Two of these, at right angles to each other, must be placed at each corner.

LIGHT FRAMING.

After the building has been laid out, and the batter boards are in place, the next work which a carpenter is called upon to do is the framing. This consists in preparing a skeleton, as we may say, upon which a more or less ornamental covering is to be placed. Just as the skeleton is the most essential part of the human body, so is the frame the most essential part of a wooden building; and upon the strength of this frame depends the strength and durability of the structure. When the carpenter comes to the work, he finds everything prepared for him; the cellar has been dug and the

foundation walls and the underpinning have been built. It is his business to raise the framework on top of them. First is the wall,

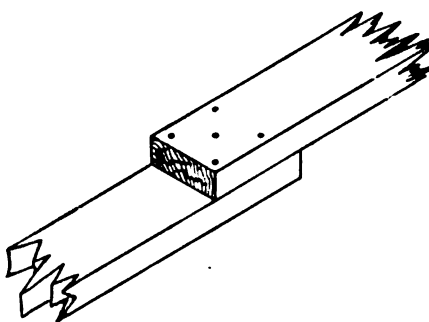


Fig. 22. Splice.

then the floors and the roof. Therefore the subject may be subdivided, and considered under these three main headings. In connection with the walls we may consider the partitions as well as the outside walls, and in connection with the floors we may consider the stairs, while the roof may be taken as comprising the main

roof and also subordinate roofs over piazzas, balconies and ells. This covers all the framing that will be found in a wooden building, except special framing, which will be treated later. Whatever framing there is in a brick or stone building is similar to that in a wooden building, with the slight differences which may be noted as we come to them.

JOINTS AND SPLICES.

Joints. Before beginning a description of the framing of the wall, it will be well to consider the methods employed in joining pieces of timber together. The number of different kinds of connections is really very small, and the principles upon which they are based may be mastered very quickly.

All connections between pieces of timber may be classified as joints or as splices. By a "splice" we mean a connection between two pieces which extend in the same direction, as shown

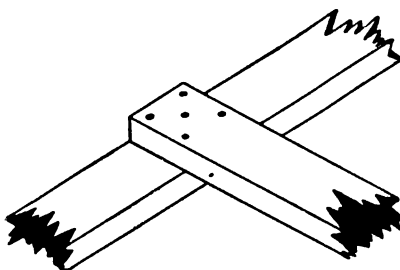


Fig. 23. Joint.

in Fig. 22, and each one of which is merely a continuation of the other. The only reason for the existence of such a connection is the fact that sticks of timber can be obtained only in limited lengths, and must therefore very often be pieced out. By a "joint" we mean any connection between two pieces which come together at an angle, as

shown in Fig. 23, and which are therefore not continuous. Such a connection may be required in a great many places, and especially at the corners of a building.

Joints. The principal kinds of joints to be met with in carpentry are the "butt joint," the "mortise-and-tenon joint," the "gained joint," the "halve l joint," the "tenon-and-tusk joint," and the "double tenon joint."

The Butt Joint. This is the most simple of all the joints, and is made by merely placing the two pieces together and nailing them firmly to each other, after both have been trimmed square and true. Such a joint is shown in Fig. 24. The two pieces are perpendicular to each other and neither piece is cut. The nails are driven diagonally through both pieces, an operation which is known as "toenailing," and are driven home, if necessary, with a nail set. This is called a "square" butt joint. Fig.

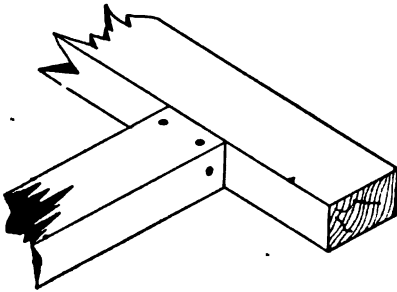


Fig. 24. Butt Joint.

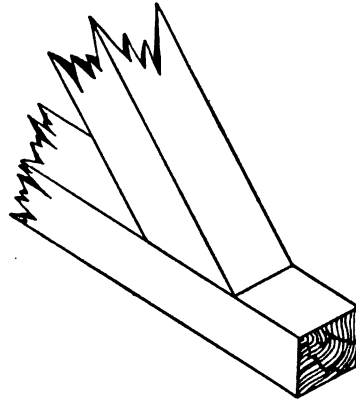


Fig. 25. Oblique Butt Joint.

25 shows two pieces which are not perpendicular to each other. They are trimmed to fit closely together, and are then nailed in place. Such a joint is called an "oblique" butt joint. The butt joint does not make a strong connection between the pieces, and should not be used if much strength is required. It depends entirely upon the nails for its strength, and these are very likely to pull out.

This form of joint is sometimes modified by cutting away a part of one of the pieces, so that the other may set down into it as shown in Fig. 26, the square joint at A, and the oblique joint at B. This gives much additional strength to the joint, especially in the case shown at B, where there may be a tendency for one piece to slide along the other.

The Mortise-and-Tenon Joint. From the modified butt joint it is only a step to the "mortise-and-tenon" joint, which is formed by cutting a hole called a "mortise" in one of the pieces of timber, to receive a projection called a "tenon" which is cut on the end of the other piece. This is shown in Fig. 27. The mortise is at *a* and the tenon at *b*. It will be noticed that there is a hole bored



Fig. 26 A.

Modified Butt Joints.

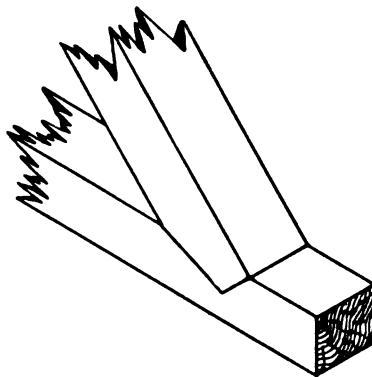


Fig. 26 B.

through the tenon at *c*, and another hole in the mortised piece at *d*. These holes are so placed that when the pieces are joined together, a wooden pin may be driven through both holes, thus preventing the tenon from being withdrawn from the mortise. This pin should *always* be inserted in a mortise-and-tenon joint. Ordinarily it is of hard wood even when the pieces to be joined are themselves of soft wood, and it may be of any desired size. Round pins from three-quarters to seven-eighths of an inch in diameter are ordinarily employed, although it may sometimes be found better to use a square pin.

The Bridge Joint. The form of mortise-and-tenon joint described above may be used wherever the pieces are perpendicular to each other. When, however, the pieces are inclined to each other, a modification of the above joint known as the "bridge" or "straddle" joint is employed. This joint is shown in Figs. 28 and 29. It is similar to the square mortise-and-tenon joint, having a similar mortise and tenon, but these are cut in a slightly different way. In Fig. 28 the tenon *a* is cut in the end of the inclined piece and fits into the mortise *b* cut in the other piece.

In Fig. 29 the mortise *a* is cut in the end of the inclined piece and the tenon *b* is cut in the other piece.

The Gained Joint. The joints which have so far been described are applicable only where the members are subjected to

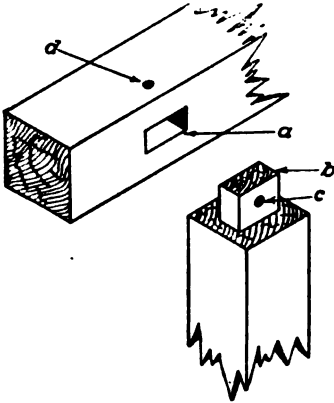


Fig. 27. Mortise-and-Tenon Joint.

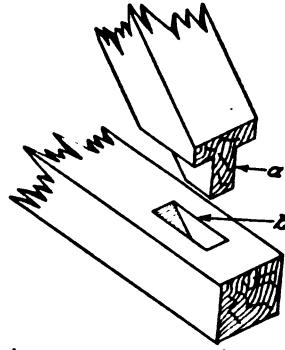


Fig. 28. Bridge Joint.

direct compression, as in the case of posts or braces, or in certain cases where direct tension is the only force acting on the pieces. When bending and shearing are to be expected, as in the case of

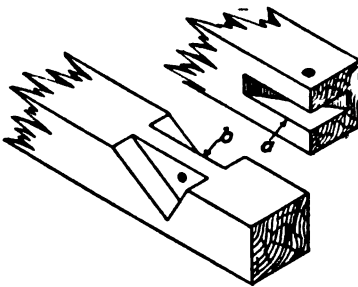


Fig. 29. Bridge Joint.

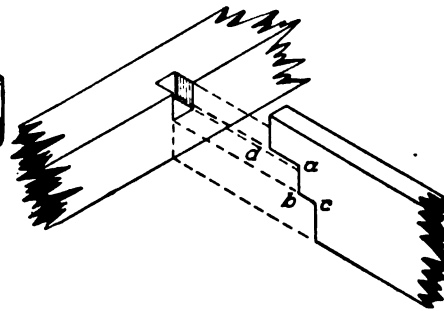


Fig. 30. Gained Joint.

floor beams connecting to sills or girders, a slightly different sort of joint must be employed.

One of the most common joints for such places is a modification of the mortise-and-tenon joint which is known as the "gained joint." An example of this form of connection is shown in Fig. 30, and it may be seen that the end of one piece is tenoned in a peculiar way. The tenon proper is the part *a-b-c* and this tenon

sets into a corresponding mortise cut in the other piece as shown. It is evident that the tenon cannot be held in place by a pin, but it may be secured by nailing.

The reason for this peculiar form of tenon may be explained as follows: A floor beam, or any other timber which is loaded transversely, has a tendency to fall to the ground, and must be supported at its ends either by resting directly on a wall or sill, or by being mortised into the latter member. Moreover, in order that the end of the piece resting on the support may not be crushed or broken, a certain amount of bearing surface must be

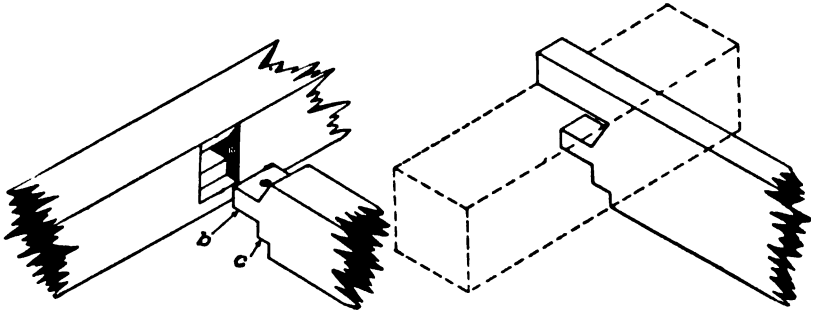


Fig. 31. Tenon-and-Tusk Joints. Fig. 32.

available. This same bearing surface must be provided in every case no matter whether the timber rests directly on the top of the sill or is mortised into it. Of course the simplest connection is obtained by resting the transverse piece directly on top of the sill without cutting either piece; but such a joint is not stiff and strong, and it is often necessary to bring the timbers flush with each other at the top or at the bottom. For this reason a mortised joint is used; and in order to obtain the required amount of bearing surface without cutting the pieces too much, the form of tenon shown is employed. The available bearing area here is furnished by the surfaces *d-a* and *b-c* and it may easily be seen that this area is the same as would be available if the piece rested directly on top of the sill.

The operation of cutting such a tenon and mortise is known as "gaining," and one piece is said to be "gained" into the other.

The Tenon-and-Tusk Joint. A joint in very common use

in such situations as have just been mentioned is a development of the gained joint which is called the "tenon-and-tusk" or the "tusk-tenon" joint. This joint is shown in Fig. 31. The characteristic feature is to be found in the peculiar shape of the tenon which is cut in the end of one of the pieces to be joined, as shown in the figure. It may be seen that there is a small square tenon *b* cut in the extreme end of the piece, and that in addition to this there are other cuts *c* which constitute the "tusk." The bearing area is furnished partly by the under side of the tenon and partly by the under side of the tusk.

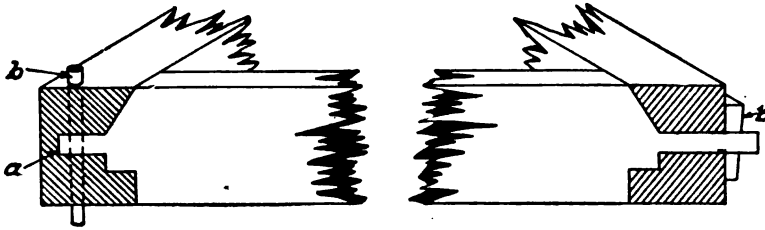


Fig. 33. Methods of Securing Tenons. Fig. 34.

This joint makes a very good connection, and the cutting of the mortise does not weaken the piece of timber so much as does the mortise for a gained joint. It is especially applicable when it is desired to have the pieces flush on top, though it may also be used in other positions. When the top of the tenoned piece must project above the top of the mortised piece, the tenon may be cut as shown in Fig. 32.

There are several ways of securing the tenon in place. The simplest is that shown in Fig. 33, where the pin *b* is passed through the tenon and the mortised piece so as to hold the tenon securely in place. Another scheme is to cut the square tenon a little longer, as shown in Fig. 34, so as to pass clear through the mortised piece, and to fasten it with a peg *b* on the other side. The peg may be cut slightly tapering, as shown, so that when it is driven in place it will draw the pieces together. Still another plan is shown in Fig. 35. Here a small square hole *a* is cut in the header some

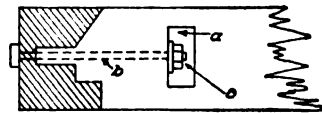


Fig. 35.
Method of Securing Tenon.

distance back from the tenon and a nut *c* is placed in it, while a bolt *b* is passed through a hole bored lengthwise in the header to receive it. The bolt passes through the nut, which may be screwed up tight, thus drawing the pieces closely together and making the joint tight. In screwing this up, it is the bolt which must be turned, while the nut is held stationary by the side of the square hole in which it is inserted and which is just large enough to receive it.

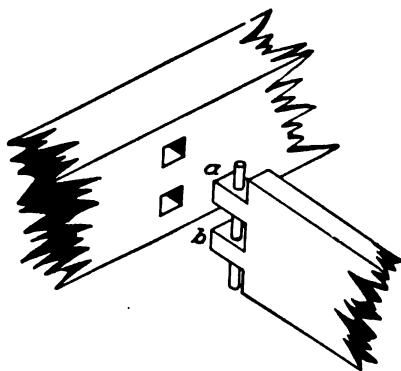


Fig. 36. Double Tenon Joint.

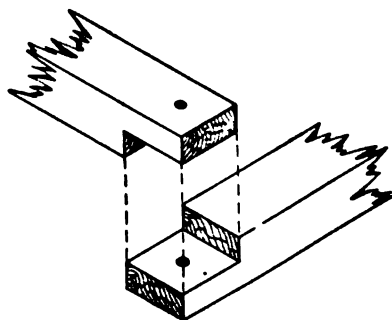


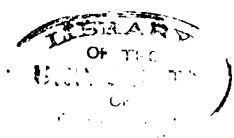
Fig. 37. Halved Joint.

The Double Tenon Joint. Fig. 36 shows a form of tenon joint called the "double tenon" joint, which is not very extensively used at the present time but which has some advantages. As may be readily seen, there are two small tenons *a* and *b* through which a pin may be passed if desired.

The Halved Joint. A form of joint which may be used to connect two pieces that meet at a corner of a building, is shown in Fig. 37.

This is known as the "halved" joint from the fact that both pieces are cut half way through and then placed together. The pieces are held in place by nails or spikes.

If one piece meets the other near the center instead of at the end of the piece, and if there is danger that the two pieces may pull away from each other, a form of joint called the "dovetail" halved joint is used. This is shown in Fig. 38. Both the tenon and the mortise are cut in the shape of a fan, or dovetail, which prevents them from being pulled apart. This joint may also be

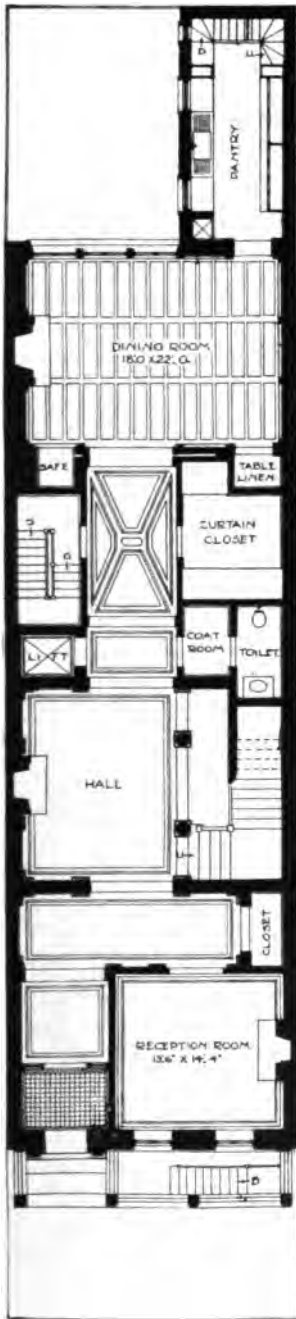




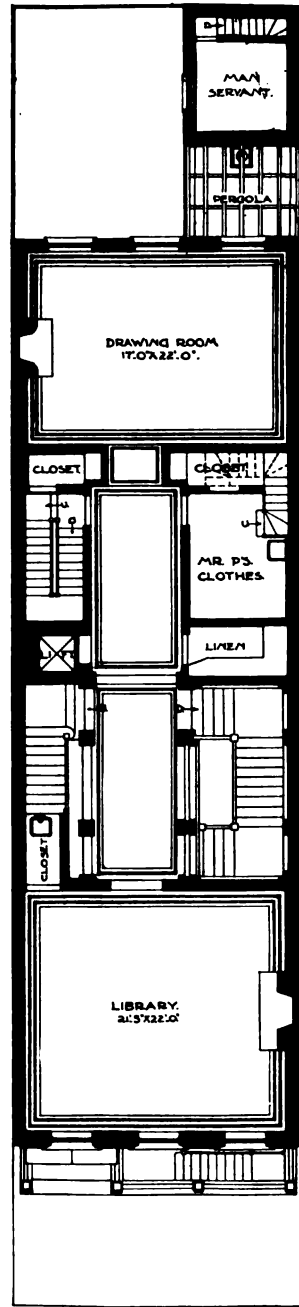
HOUSE AT 123 EAST 73d STREET, NEW YORK CITY

R. Burnside Potter, of Robertson & Potter, Architect, New York.

Front of A. B. C. Brick. Door and Fence, Wood, Painted; Walls and Lintels, Crema
Marble; Cornice and Dormers, Copper, Painted; Roofs of Slate. Cost,
about \$70,000. An Excellent Example of a Simple, Dignified
Treatment for a Narrow City Lot. The Treatment of
the Roof, to Give a Low Effect, is Particu-
larly Good. For Plans, See
Opposite Page.



GROUND FLOOR.



FIRST FLOOR.

PLANS OF HOUSE AT 123 EAST 73d STREET, NEW YORK CITY

R. Burnside Potter, of Robertson & Potter, Architect, New York.

Finish Floors from Ground to First Floor. Teak; above that, North Carolina Pine. Drawing Room Paneled Completely in Wood, Painted; and Walls throughout Rest of House Hung in Silk and Other Materials. Front View of House Exterior Shown on Opposite Page.



cut as shown in Fig. 39, with the flare on only one side of the tenon, the other side being straight.

Splices. As already explained, a splice is merely a joint between two pieces of timber which extend in the same direction, and is sometimes necessary because one long piece cannot be conveniently or cheaply obtained. The only object in view, then, is

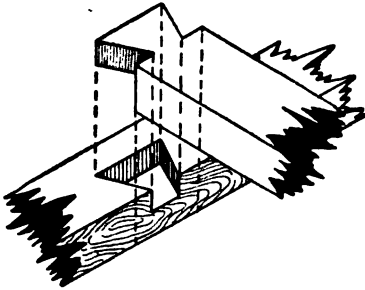


Fig. 38. Dovetail Halved Joint.

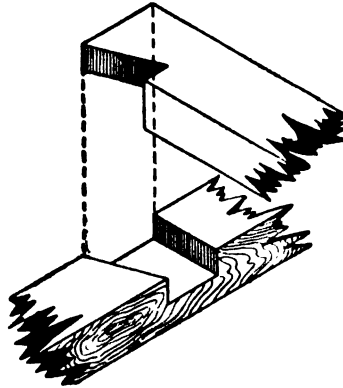


Fig. 39. Dovetail Joint.

to fasten the two timbers together, in such a way that the finished piece will be in all respects equivalent to a single unbroken piece, and will satisfy all the requirements of the unbroken piece. This is really the only measure of the efficiency of a splice.

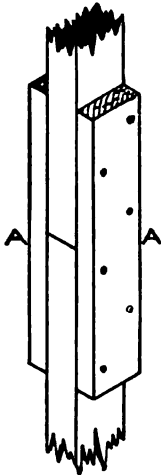


Fig. 40.
Fished Splice.

There are three kinds of forces to which a piece may be subjected, namely: compression, tension, and bending. A splice which would be very effective in a timber acted upon by one of these forces might be absolutely worthless in a piece which must resist one of the other forces. We have, therefore, three classes of splices, each designed to resist one of these three forces.

Splices for Compression. The simplest splices are those to resist compression alone, and of these the most simple is that shown in Fig. 40. This piece is said to be "fished;" the two parts are merely sawed off square and the ends placed together. A couple of short pieces A A, called "fish plates" are

nailed on opposite sides to keep the parts in line. In the splice shown in Fig. 40, these are of wood, and ordinary nails are used to fasten them in place, but in more important work thin iron plates are used, the thickness being varied to suit the conditions. They are held in place by means of bolts with washers and nuts.

If for any reason, it is desired not to use plates of this kind, four small pieces called dowels may be used, as indicated in Fig. 41. These dowels may be set into the sides of the timbers to be spliced, so that they do not project at all beyond the faces of these pieces and a very neat job may thus be obtained.

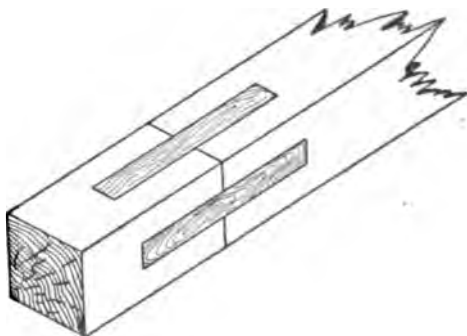


Fig. 41. Splice Using Dowels.

It is but a step to pass from this simple splice to the "halved" splice shown in Fig. 42. It will be noticed that it is much like the halved joint described above, the only difference being that the pieces are continuous, instead of perpendicular to each other. The nature of the splice will be easily understood from the figure

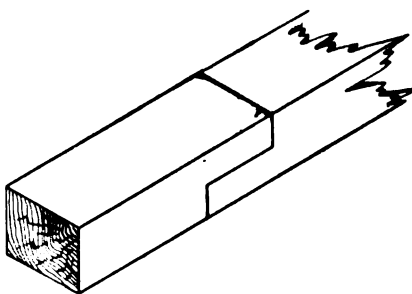


Fig. 42. Halved Splice.

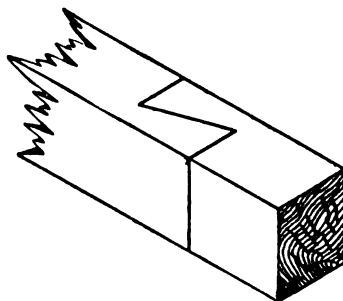


Fig. 43. Beveled Splice.

without further explanation. A modification of this which is somewhat more effective, is shown in Fig. 43. The cuts are here made on a bevel in such a way that the parts fit accurately when placed together, and the splice is called a "beveled" splice.

The halved splice is perhaps the best that can be used to

resist direct compression, and when it is combined with fish plates and bolts as shown in Fig. 44 it may be used in cases where some tension is to be expected. It will be noticed that in Fig. 44 the ends of the timbers are cut with a small additional tongue *a* but this does not materially strengthen the splice and it adds considerably to the labor of forming it. In general it may be said that the simplest splice is the most effective.

Whenever the pieces are cut to fit into one another, as they do in the halved and beveled splices, the splice is known as a "scarf" splice, and the operation of cutting and joining the parts is called "scarfing." Scarf splices are used, as we have already seen, both alone and in combination with fish plates. The fished splice is always the stronger, but the splice where scarfing alone is resorted to has the neatest appearance.

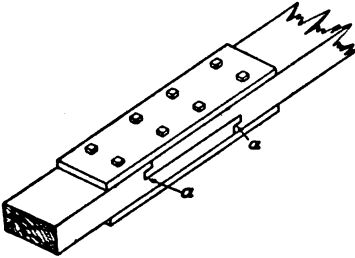


Fig. 44. Halved Splice with Fish Plates.

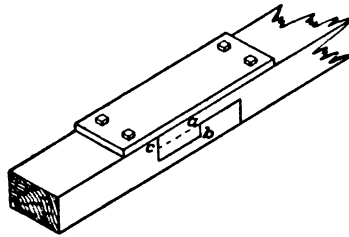


Fig. 45. Splice for Tension.

Splices for Tension. There are several common forms of splices for resisting direct tension. These differ from each other mainly in the amount of labor involved in making them. The simplest of them is shown in Fig. 45, and it will be seen that it is only a slight modification of the halved splice used for resisting compression. It is evident that the pieces cannot pull apart in the direction of their length until the timber crushes along the face marked *a-b*, or shears along the dotted line *a-c*. By varying the dimensions of the splice it may be made suitable for any situation. The parts are held closely together by the light fishplates shown in the figure, which also incidentally add something to the strength of the splice.

Instead of cutting the ends of the beams square, as shown in Fig. 45, they frequently are cut on a bevel as shown in Fig. 46,

and a further modification may be introduced by inserting a small "key" of hard wood between the pieces for them to pull against. This key is usually made of oak and may be in two parts, as shown in Fig. 47, each part in the shape of a wedge, so that when they are driven into place a tight joint may be obtained. The two wedge-shaped pieces may be driven in from opposite sides, the hole being made a little smaller than the key. If the key is made

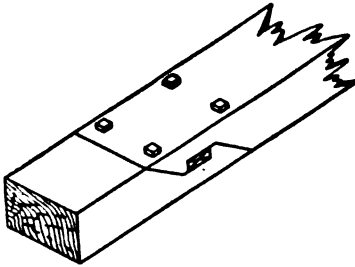


Fig. 46. Splice for Tension.

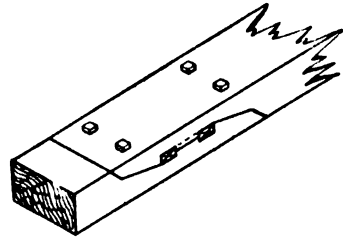


Fig. 47. Splice with Two Keys.

much too large for the hole, however, a so-called "initial" stress is brought into the timbers, which uses up some of their strength even before any load is applied. This should be avoided.

If it is desired, two or more keys may be employed in a splice, the only limiting condition being that they must be placed far enough apart so that the wood will not shear out along the dotted line shown in Fig. 47. Another feature of the splice here shown

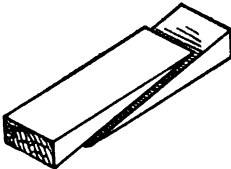


Fig. 48. Keys.

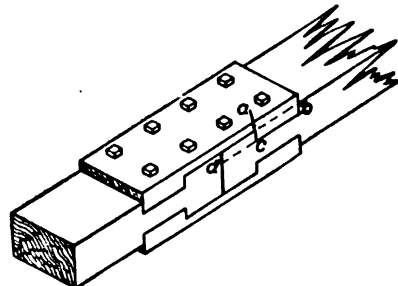


Fig. 49. Tension Splice with Fish Plates.

is the way in which the pieces are cut with two bevels on the end instead of one. One bevel starts at the edge of the key and is very gradual, the other starts at the extreme end of the piece and

is rather steep and sharp. These bevels can be used only in joints which resist tension alone. If such a splice were subjected to compression, the beveled ends would slide on each other and push by each other very easily, except as they are prevented from so doing by the fish plates, if these are used.

Tension Splice with Fish Plates. The splices for tension which have so far been described have all been scarf joints, but there is a fished splice which is very commonly used for tension. This splice is shown in Fig. 49. The fish plates, in this case of wood, are cut into the two pieces to be spliced, so as to hold them firmly together. The pieces cannot be pulled apart until one of the plates shears off along the dotted line *a-b*. The distance *c-d* must also be made large enough so that the piece will not shear. This splice is very often used for the lower chords of wooden trusses, and it is really one of the best that can be used for resisting direct tension.

Splices for Bending. It sometimes happens that a piece which is subjected to a bending stress must be spliced, and in this case the splice must be formed to suit the existing conditions. It is well known that in a timber which is resisting a bending stress the upper part of

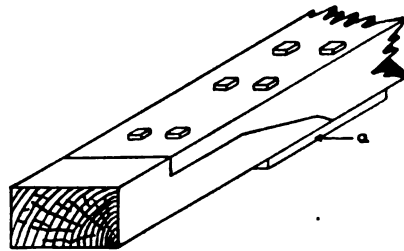


Fig. 50. Splice for Bending.

the piece is in compression, and the tendency is for the fibers to crush, while the lower part of the piece is in tension, and the tendency is for the fibers to pull apart. To provide for this, a form of splice must be selected which combines the features of the tension and compression splices. Fig. 50 shows such a splice. The parts are scarfed together as in the case of the other splices described, but in this case the end of the top piece is cut off square to offer the greatest possible resistance to crushing, while the underneath piece is beveled on the end, as there is no tendency for the timbers to crush. These cuts are shown in the figure.

We have already seen that in the lower part of the splice

there is a tendency for the parts to be pulled away from each other. In order to prevent this, a fish plate *a* is used, which must be heavy enough to take care of all the tension, since it is evident that the wood cannot take any of this. The plate must be securely bolted to both parts of the splice. There is no need of a fish plate on the top of the pieces because there is no tendency for the pieces to pull apart on top, and the bolts shown in the figure are sufficient to prevent them from being displaced.

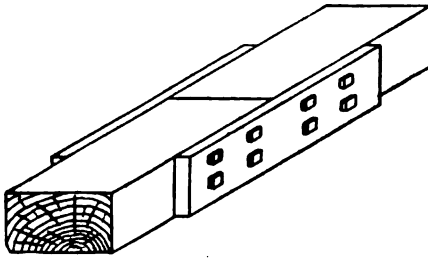


Fig. 51. Butt Joint.

In any case where it is not desirable to scarf the pieces in a splice subjected to bending, the form of butt joint shown in Fig. 51 may be used. The plates (either of wood or iron) are in this case bolted to the sides of the pieces. If wood is used, of course the plates must be made very much heavier than if iron is used.

In either case they must be large enough to take care of all the bending stress, and a sufficient number of bolts must be used to fasten them securely to both parts of the splice.

THE WALL.

Let us next consider the framing of the walls of the building. In this work there are two distinct methods known respectively as "braced framing" and "balloon framing," of which the first is the older and stronger method, while the second is a modern development and claims to be more philosophical, as well as more economical, than the other. Balloon framing has come into use only since 1850, and is still regarded with disfavor by many architects, especially in the eastern states. Figs. 52 and 53 show the framing of one end of a small building by each of these methods, the braced framing in Fig. 52, and the balloon framing in Fig. 53.

Braced Frame. In a full-braced frame all the pieces should be fastened together with mortise-and-tenon joints, but this is much modified in common practice, a so-called "combination" frame being used, in which some pieces are mortised together and

others are fastened by means of spikes only. A framework is constructed consisting in each wall of the two "corner posts" A A (Fig. 52), the "sill" B, and the "plate" C, together with a horizontal "girt" D at each story, to support the floors, and a diagonal "brace" E at each corner, which, by keeping the corner square, prevents the frame from being distorted.

Balloon Frame. In a balloon frame there are no braces or girts; and the intermediate studs F F F (Fig. 53) are carried straight up from the sill H to the plate K, with a light horizontal piece J, called a "ribbon" or "ledger board," set into them at each floor level to support the floors. This frame depends mainly

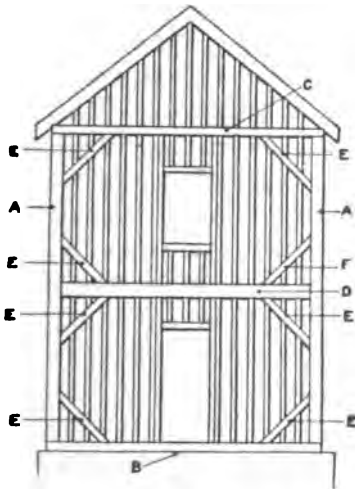


Fig. 52. Braced Frame.

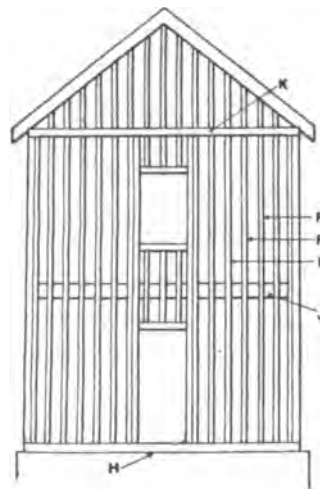


Fig. 53. Balloon Frame.

upon the boarding for its stiffness, but sometimes light diagonal braces are set into the studs at each corner to prevent distortion. The methods by which all these pieces are framed together will be explained in detail under the proper headings.

The Sill. The sill is the first part of the frame to be set in place. It rests directly on the underpinning and extends all around the building, being jointed at the corners and spliced where necessary; and since it is subject to much cutting and may be called upon to span quite considerable openings (for cellar windows, etc.) in the underpinning, it must be of good size. Usually it is made of six by six square timber, but in good work

it should be six by eight, and nothing lighter than six by six should be used except for piazza sills. For piazza sills a four by six timber is used. The material is generally spruce, although sometimes it is Norway pine or native pine (depending upon the locality).

The sill should be placed on the wall far enough back from the outside face to allow for the water table, which is a part of the outside finish; and one inch should be regarded as the minimum distance between the outside face of the sill and the outside face of the underpinning (see Fig. 54). A bed of mortar A, preferably of cement mortar, should be prepared on the top of the underpinning, in which the sill C should rest; and the under side of the sill should be painted with one or two coats

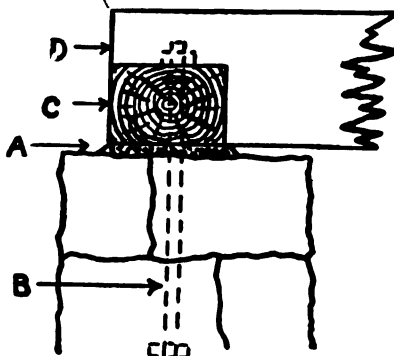


Fig. 54. Sill Placed on Wall.

of linseed oil to prevent it from absorbing moisture from the masonry. In many cases, at intervals of eight or ten feet, long bolts B are set into the masonry. These bolts extend up through holes bored in the sill to receive them, and are fastened at the top by a washer and a nut screwed down tight. They fasten the sill, and consequently the whole frame, securely to the underpinning, and should always be provided in the case of light frames in exposed positions.

The beams or "joists" D, which form the framework of the first floor, are supported at one or both ends by the sill and may be fastened to it in any one of several different ways. The ideal method is to hang the joist in a patent hanger fastened to the sill as shown in Fig. 55, where A is the sill, B the joist, and C the hanger. In this case neither the sill nor the joist need be

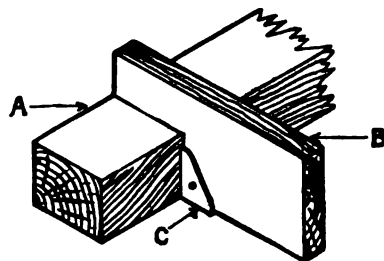


Fig. 55. Patent Hanger.

weakened by cutting, but this is too expensive a method for ordinary work, although the saving in labor largely offsets the cost of the hanger. The usual method is to cut a mortise in the sill to receive a tenon cut in the end of the joist (as shown at A in Fig. 56). These mortises are cut in the inside upper corner of the sill, are about four inches deep and cut two inches into the width of the sill, and are fixed in position by the spacing of the joists.

Mortises are also cut in the sill to receive tenons cut in the lower ends of the studs (as shown at B in Fig. 57). They are cut the full thickness of the studding, about one and one-half inches in the width of the sill and about two inches deep. The position of these is fixed by the spacing of the studding, and by the condition that the outer face of the studding must be flush with the outer face of the sill in order to leave a plain surface for the boarding.

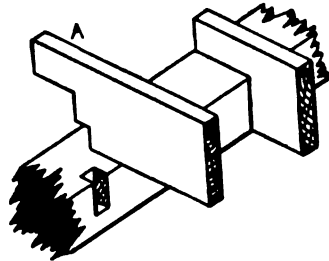


Fig. 56. Mortise in Sill.

The sills are usually halved and pinned together at the corners, as shown in Fig. 58; but sometimes they are fastened together by means of a tenon A cut in one sill, which fits into a mortise cut

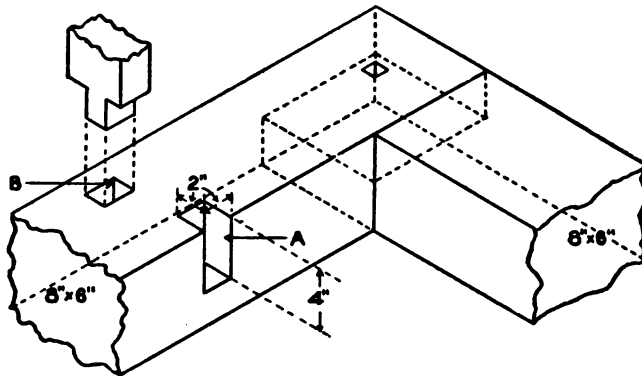


Fig. 57. Mortise in Sill for Studding.

in the other, as shown in Fig. 59. This may be stronger than the other method, but the advantage gained is not sufficient to compensate for the extra labor involved. Sills under twenty feet in

length should be in one piece, but in some cases splicing may be necessary. A scarf joint should always be used, the splice should be made strong, and the pieces should be well fitted together.

In some parts of the country it is customary to "build up" the sill from a number of planks two or three inches thick, which

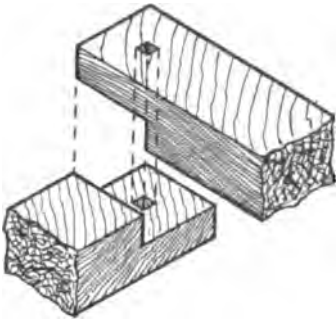


Fig. 58. Joint of Sills at Corner.

are spiked securely together. A six-by-six-inch sill may be made in this way from three planks, two inches thick and six inches wide, as shown in Fig. 60. Planks of any length may be used, and may be so arranged as to break joints with each other so that the sill may be made continuous, without splicing. It is often easier and cheaper to build up a sill in this way than it is to use a large, solid

timber, and if the parts are well spiked together, such a sill is fully as good as the other. When a sill of this kind is used, however, it should always be placed on the wall in such a way that the planks of which it is made up will set up on edge and not lie flat.

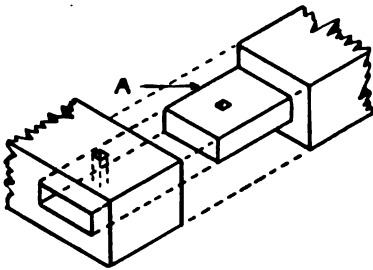


Fig. 59. Joint of Sills at Corner.

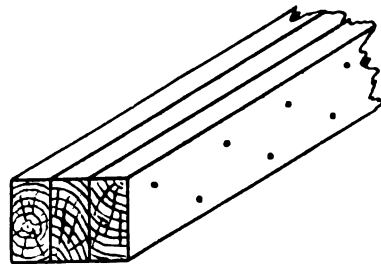


Fig. 60. "Built-up" Sill.

The Corner Posts. After the sill is in place, the first floor is usually framed and roughly covered at once, to furnish a surface on which to work, and a sheltered place in the cellar for the storage of tools and materials, after which the framing of the wall is continued. The corner posts are first set up, then the girts and the plate are framed in between them, with the braces at the corners to keep everything in place; and lastly the whole is filled in with studding. The corner posts are pieces four by eight, or

sometimes two pieces four by four placed close together. Corner posts must be long enough to reach from the sill to the plate. The post is really a part of only one of the two walls which meet at the corner, and in the other wall a "furring stud" of two-by-four stuff is placed close up against the post so as to form a solid

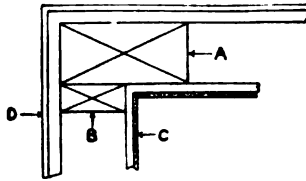


Fig. 61. Corner Post with One Furring Stud.

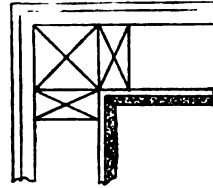


Fig. 62. Corner Post with Two Furring Studs.

corner, and give a firm nailing for the lathing in both walls. This arrangement is shown in plan in Fig. 61. A is the corner post, B the furring stud, C the plastering, and D the boarding and shingling on the outside. Sometimes a four-by-four piece is used for the corner post and a two-by-four furring stud is set close against it in each wall to form the solid corner, as shown in plan in Fig. 62; but a four-by-four-stick is hardly large enough for the long corner post, and the best practice is to use a four-by-eight, although in very light framing a four-by-six might be used. A tenon is cut in the foot of the corner post to fit a mortise cut in the sill, and mortises *c c*, Fig. 63, are cut in the post at the proper level to receive the tenons cut in the girts. Holes must also be bored to receive the pins *d d* which fasten these members to the post.

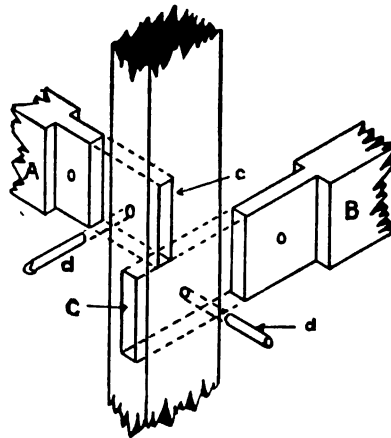


Fig. 63. Mortises in Corner Post.

The braces are often only nailed in place, but it is much better to cut mortises in the posts for these also, as shown at A in Fig. 64. The plate is usually fastened to the posts by means of spikes only, but it may be mortised to receive a tenon cut in the top of the post.

In the case of a balloon frame no mortises need be cut in the posts for the girts or braces, as they are omitted in this frame; but the post must be notched instead, as shown in Fig. 65, to receive the ledger board or ribbon and the light braces which are sometimes used.

The Girts. The girts are always made of the same width as the posts, being flush with the face of the post both outside and inside, and the depth is usually eight inches, although sometimes a six-inch timber may be used. The size is, therefore, usually four by eight. A tenon at each end fits into the mortise cut in the

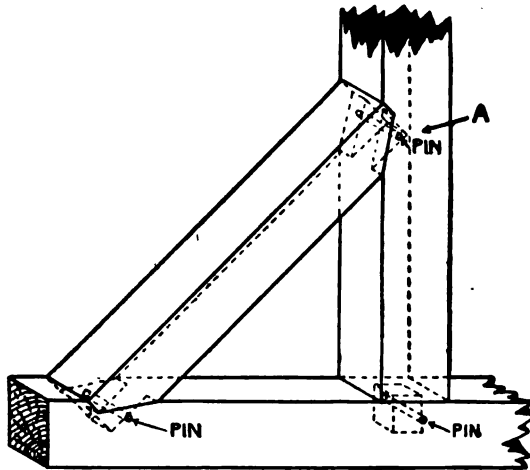


Fig. 64. Brace for Post and Sill.

post, and the whole is secured by means of a pin *d d* as shown in Fig. 63. The pin should always be of hard wood and about seven-eighths inch in diameter. It is evident that if the girts in two adjacent walls were framed into the corner post at the same level, the tenons on the two girts would conflict with each other. (See Fig. 63.) For this reason the girts *A* which run parallel with the floor joists are raised above the girts *B* on which these joists rest, and are called "raised girts" to distinguish them from the others which are called "dropped girts." The floor joists are carried by the dropped girts, and the raised girts are so placed that they are just flush on top with the joists which are parallel to them.

The Ledger Board. The heavy girts are used only in the

braced frame. In the balloon frame, light pieces called "ledger boards" or "ribbons" are substituted for them. These are usually made about one inch thick and six or seven inches deep, and are notched into the posts and intermediate studs instead of being



Fig. 65.

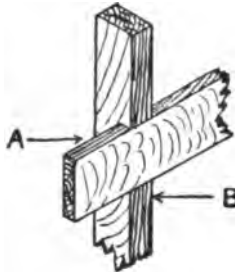


Fig. 66.

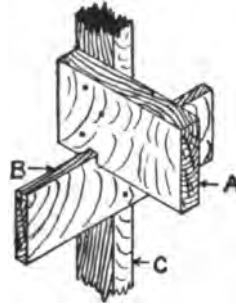


Fig. 67.

Notched Studs for Ledger Boards.

framed into them as in the braced frame. This notching is shown in Fig. 66 in which A is the ledger board and B the stud. The ledger boards themselves are not cut at all, but the floor joists which they carry are notched over them, as shown in Fig. 67, and spiked to them and to the studding. In Fig. 67 A is the joist, B the ledger board, and C the stud. Even in the braced frame a ledger board is usually employed to support the joists of the attic floor, which carry little or no weight. The disadvantage of the ledger board is that as a tie between the corner posts it is less effective than the girt, and consequently a wall in which it has been substituted for the girt is not as stiff as one in which the girt is used.

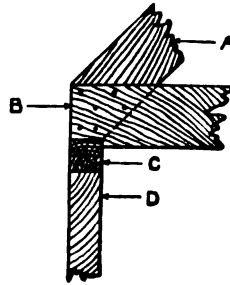


Fig. 68.

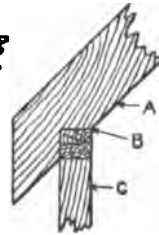


Fig. 69.

Construction at Plate.

The Plate. The plate serves two purposes: first, to tie the studding together at the top and form a finish for the wall; and second, to furnish a support for the lower ends of the rafters. (See Fig. 68). It is thus a connecting link between the wall and the roof, just as the sill and the girts are connecting links between

the floors and the wall. Sometimes the plate is also made to support the attic floor joists, as shown in Fig. 68, in which A is a rafter, B the joist spiked to the rafter, C the plate built up from two two-by-four pieces, and D the wall stud. It acts in this case like a girt, but this arrangement is not very common, the attic floor joists usually being supported on a ledger board as shown in Fig. 67. The plate is merely spiked to the corner posts

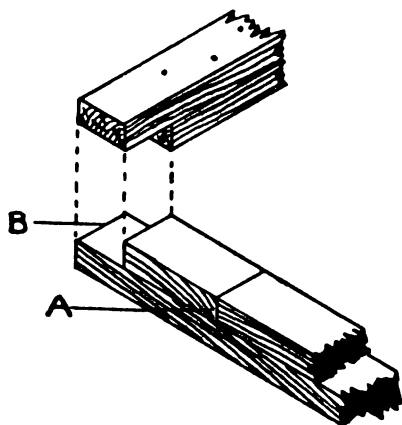


Fig. 70. Construction at Corner,
"Breaking Joints."

and to the top of the studding; but at the corner where the plates in two adjacent walls come together, they should be connected by a framed joint, usually halved together in the same way as the sill. In the braced frame, a fairly heavy piece, usually a four by six, is used, although a four by four is probably sufficiently strong. In a balloon frame the usual practice is to use two two-by-four pieces placed one on top of the other and breaking joints, as

shown at A in Fig. 70, in order to form a continuous piece. The corner joint is then formed, as shown at B in Fig. 70. No cutting is done on the plate except at the corners, the rafters and the attic floor joists being cut over it, as shown in Figs. 68 and 69.

Braces. Braces are used as permanent parts of the structure only in braced frames, and serve to stiffen the wall, to keep the corners square and true, and to prevent the frame from being distorted by lateral forces, such as wind. In a full-braced frame, a brace is placed wherever a sill, girt, or plate makes an angle with a corner post, as shown at E in Fig. 52. Braces are placed so as to make an angle of forty-five degrees with the post, and should be long enough to frame into the corner post at a height of from one-third to one-half the height of the story. This construction is often modified in practice, and the braces are placed as shown at A in Fig. 71. Such a frame is not quite so stiff and strong as the regular braced frame, but it is sufficiently strong in most cases.

The braces are made the same width as the posts and girts, usually four inches, to be flush with these pieces both outside and inside, and are made of three-by-four or four-by-four stuff. They are framed into the posts and girders or sills, by means of a tenon cut in the end of the brace, and a mortise cut in the post or girt, and are secured by a hardwood pin. The pin should be three-quarters or seven-eighths inch in diameter. The connection is shown in Fig. 64.

In a balloon frame, there are no permanent braces, but light strips are nailed across the corners while the framework is being erected, and before the boarding has been put on, to keep the frame in place. As soon as the outside boarding is in place these are removed. This practice is also modified, and

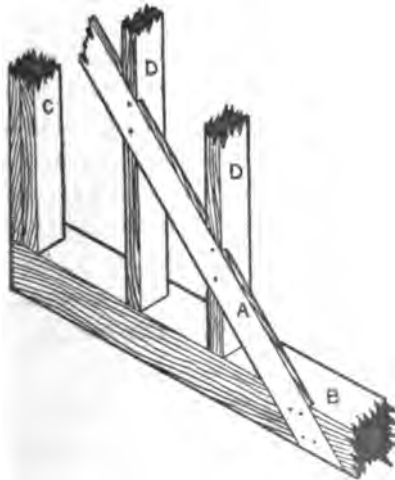


Fig. 72. Temporary Brace.

sometimes light braces are used as permanent parts of even a balloon frame. They are not framed into the other members, however, but are merely notched into them

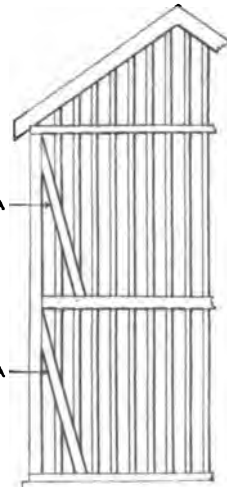


Fig. 71. Braced Frame.

and spiked as shown in Fig. 72. A is the brace, B the sill, C the corner post, and D D are studs. In such a case every stud must be notched to receive the brace, which is really the same as the temporary brace mentioned above, except that it is notched into the studs instead of being merely nailed to them, and is not removed when the boarding is put on. These braces are usually made of one-by-three-inch stuff.

Studding. When the sill, posts, girts, plates, and braces are

for the door and window openings, and the stops for the partitions; and the lighter pieces which are merely "filling-in" studs, and which are known by that name, or as "intermediate" studding.

The frames for the door and window openings are usually made in a braced frame, from four-by-four-inch pieces. A vertical stud A A, Fig. 73, is placed on each side of the opening, the proper distance being left between them, and horizontal pieces B B are framed into them at the proper level to form the top and the bottom of the opening. In all good work a small truss is

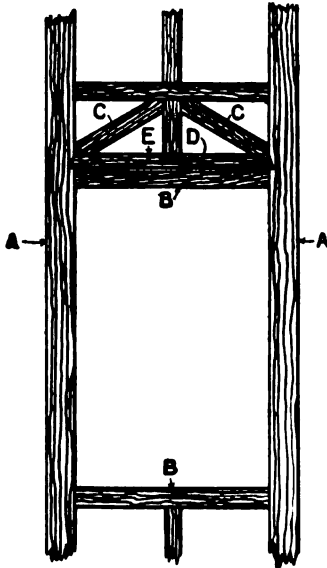


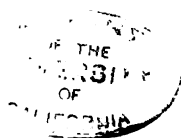
Fig. 73. Truss over Window.

formed above each opening by setting up two pieces of studding C C over the opening, in the form of a triangle. This is to receive any weight which comes from the studding directly above the opening, and carry it to either side of the opening where it is received by the studding and in this way carried down to the sill. Such a truss is shown in Fig. 73. The pieces used are three by four or four by four, and may be either framed into the other members or merely spiked. There should be a space D of at least one inch between the piece B forming the top of the window frame and the piece E forming the bottom of the truss, so that if

the truss sags at all it will not affect the window frame. This is a point that is not generally recognized. The piece B is usually made to serve both as the top of the window and the bottom of the truss.

Fig. 74 shows the framing for the top of a window opening in a balloon-framed building, where the ledger-board is partly supported by the studs directly over the opening. Since the floor joists rest on the ledger-board, there may be considerable weight carried onto these studs; and to prevent the bottom of the truss from sagging under this weight, a rod should be inserted as shown.





In the balloon frame, the door and window studs are almost always made of two two-by-four pieces placed close together, and in this case the connection of the pieces forming the top and

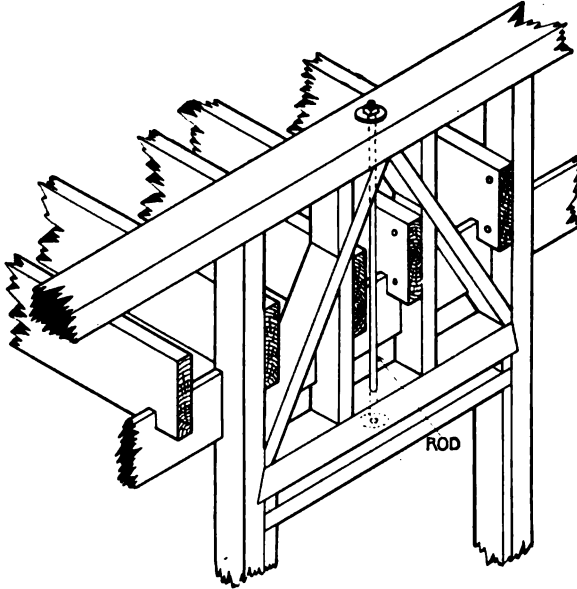


Fig. 74. Truss over Window. Balloon Frame.

bottom of the frame with those forming the sides is made as shown at A in Fig. 75. It should be noticed that in a balloon frame all studding is carried clear up from the sill to the plate, so that if there is an opening in the wall of the first story, and no corresponding openings in those of the second or third story, the door and window studding must still be carried double, clear up to the plate, and material is thus wasted. In designing for balloon frames, therefore, it is well to take care that the window openings in the second story come directly above those in the first story wherever this is possible. The same difficulty does not occur in the case of a braced frame, because in such a frame the studding in each story is independent of that in the story above or below it, and the openings may be arranged independently in the different stories.

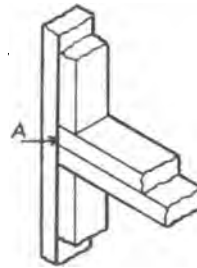


Fig. 75.

Nailing Surfaces. Wherever a partition meets an outside wall, a stud wide enough to extend beyond the partition on both sides and afford a solid nailing for the lathing must be inserted. A nailing surface must be provided for the lathing on both the outside wall and the partition, and the first stud in the partition wall is therefore set close up against the wall stud, forming a solid corner. This arrangement is shown in plan in Fig. 76. The large wall stud A is usually made of a four-by-eight piece set flat-wise in the wall so that if the partition is, say, four inches wide, there is a clear nailing surface of two inches on each side of the partition. A four-by-six piece could also be used here, leaving a clear nailing surface of one inch on each side of the partition.

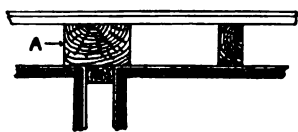


Fig. 76.

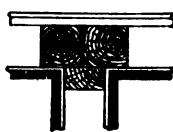


Fig. 77.

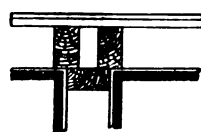


Fig. 78.

Arrangement of Studding for Nailing Surfaces.

Sometimes the same thing is accomplished by using two four-by-four pieces placed close together as shown in plan in Fig. 77, instead of one four-by-eight piece. Sometimes two pieces, two-by-four or three-by-four, are used, placed far enough apart so that they afford a space for nailing on each side of the partition, as shown in plan in Fig. 78. Whenever this is done, small blocks A, Fig. 79, should be cut in between the two studs at intervals of two to three feet throughout their height, to give them added stiffness and make them act together.

The end in view in every case is to obtain a solid corner on each side of the partition where it joins the wall, and any construction which accomplishes this is good. In the best work, however, the four-by-eight solid piece is used, and this construction can always be depended upon. It makes no difference what the angle between the wall and the partition may be, but usually this angle is a right angle.

Intermediate Studding. The pieces which make up the largest part of the wall frame are the "filling-in," or "intermediate" studs. These, as the name implies, are used merely to fill up the frame made by the other heavier pieces, and afford a nail-

ing surface for the boarding, which covers the frame on the outside, and the lathing, which covers it on the inside. The filling-in studs are usually placed sixteen inches apart, measured from the center of one stud to the center of the next. In especially good work they are sometimes placed only twelve inches apart on centers, but this is unusual. In no case should they be placed more than sixteen inches apart, even in the lightest work. The studs are made the full width of the wall, usually four inches, but sometimes in large buildings (such as churches) five or even six inches. They are almost always two inches thick, two by four being the ordinary dimensions for studding, and the lengths are cut to fit the rest of the frame.

In the braced frame, there must necessarily be a great deal of cutting of the intermediate studding, because all the large pieces are made the full width of the wall, and the intermediate studding must be cut to fit between them. In the balloon frame, however, the intermediate studding in all cases extends clear up from the

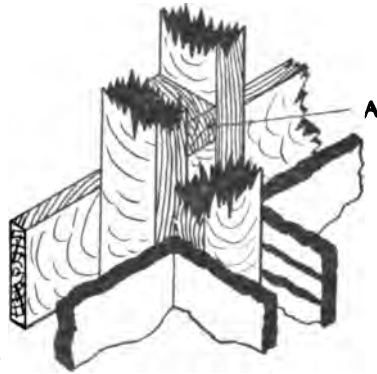


Fig. 79. Wall Studding.

sill to the plate, and no cutting is necessary except the notching to receive the other parts of the frame. (See Fig. 53.)

In a balloon frame it often happens that the studs are not long enough to reach from the sill to the plate and they must be pieced out with short pieces which are spliced onto the long stud. This splicing is called "fishing," and it is accomplished by nailing a short, thin strip of wood A A on each side of the stud as shown in Fig. 40 in order to join the two pieces firmly together. The strips should be well nailed to each piece.

All door and window studs should have a tenon cut at the foot of the piece to fit a mortise cut in the sill. Intermediate studs are merely spiked to the sill without being framed into it. The tenons are cut in two different ways, as shown in Figs. 80 and 81. They are always made the full thickness of the piece, and by the first method they are placed in the middle of the

piece, as shown. The width of the tenon is about one and one-half inches, leaving an inch and a-half on the outside and one inch on the inside of the stud. Another way is to make the tenon on the inside of the stud, as shown in Fig. 81, the tenon being an inch and a-half wide as before. There is no choice between these two methods, both being good.

Partitions. The studding used in partition walls is usually of two-by-four stuff, although two-by-three studding may sometimes be used to advantage if the partition does not support any floor joists.

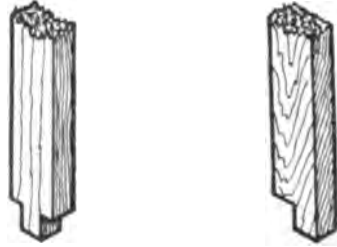


Fig. 80. Tenons for Studs. Fig. 81.

The partition walls are made four inches wide, the same as in the outer walls, except in the case of so-called "furring" partitions. These are built around chimney breasts and serve to conceal the brickwork and furnish a surface for plastering. They are formed by placing the studding flatwise, in order to make a thin wall; and as it is usually specified that no woodwork shall

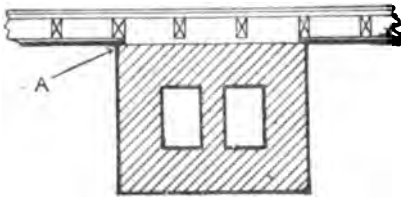


Fig. 82. Plastering around Chimney.

come within one inch of any chimney, a one-inch space is left between the brickwork and the furring wall. It is possible to apply the plaster directly to the brickwork, and this is sometimes done, but there is always danger that cracks will appear in the

plastering at the corner A, Fig. 82, between the chimney breast and the outside wall. This cracking is due to the unequal settlement of the brickwork and the woodwork, since the plastering goes with the wall to which it is applied. The method of constructing the furring wall is shown in plan in Fig. 83. A A are the furring studs, B is the plastering, and C C the studding in the outside wall. The arrangement without the furring wall is shown in plan in Fig. 82. If there are any openings in the furring wall such as fireplaces, or "thimbles" for stove pipes, it is necessary to frame around them in the same way as was explained for door and window openings in the outside walls.

See Fig. 84. A A are furring studs, B B are pieces forming the top and bottom of the opening.

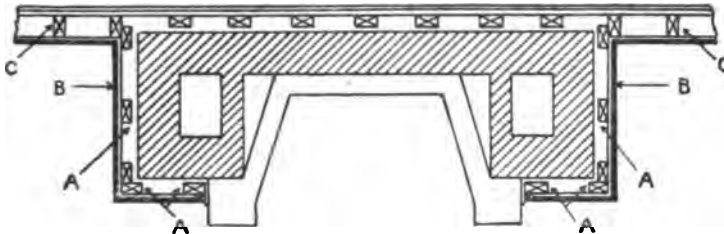


Fig. 83. Furring Wall around Chimney.

Masonry Walls. If the outside walls of the building are of brick or stone, a wooden "furring" wall is usually built just inside of the outer wall; this furnishes a surface for plastering and for nailing the inside finish. The studding for these walls is two-by-four or two-by-three set close up against the masonry wall

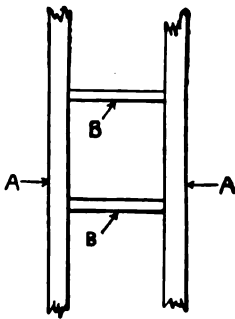


Fig. 84. Opening for Thimble.

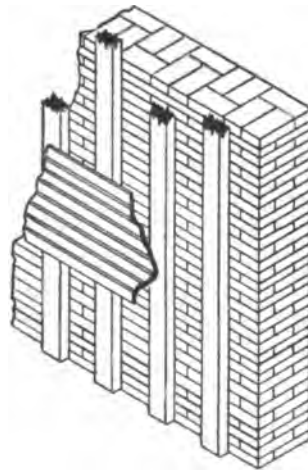


Fig. 85. Furring for Brick Wall.

and preferably spiked to it (see Fig. 85). Spikes are usually driven directly into the mortar between the bricks or stones of the wall, but sometimes wooden blocks or wedges are inserted in the masonry wall to afford a nailing.

Wherever a wooden partition wall meets a masonry exterior wall at an angle, the last stud of the partition wall should be

securely spiked to the masonry wall, to prevent cracks in the plastering.

Cap and Sole. All partition walls are finished at the top and bottom by horizontal pieces, called respectively the cap and the sole. The sole rests directly on the rough flooring whenever there is no partition under the one which is being built; but if there is a partition in the story below, the cap of the lower partition is used as the sole for the one above. The sole is made wider than the studding forming the partition wall, so that it projects somewhat on each side and gives a nailing for the plasterer's

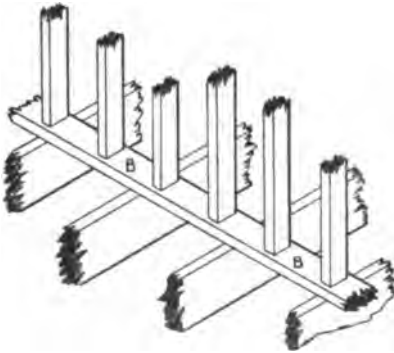


Fig. 86. Sole Piece.

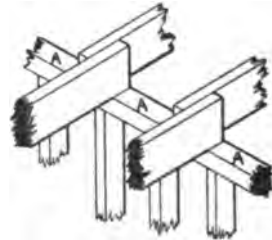


Fig. 87. Partition Cap.

grounds and for the inside finish. It is usually made about two inches thick and five and a-half inches wide, when the partition is composed of four-inch studding, and this leaves a nailing surface of three-quarters of an inch on each side. The sole is shown at B in Fig. 86. The cap is usually made the same width as the studding, and two inches thick, so that a two-by-four piece may be used in most cases; but if the partition is called upon to support the floor beams of the floor above, the cap may have to be made three or even four inches thick, and some architects favor the use of hardwood such as Georgia pine for the partition caps. The cap is shown at A, Fig. 87.

Bridging. In order to stiffen the partitions, short pieces of studding are cut in between the regular studding in such a way as to connect each piece with the pieces on each side of it. Thus, if one piece of studding is for any reason excessively loaded, it will

not have to carry the whole load alone but will be assisted by the other pieces. This operation is called "bridging," and there are two kinds, which may be called "horizontal bridging" and "diagonal bridging." The horizontal bridging consists of pieces set in horizontally between the vertical studding to form a continuous horizontal line across the wall, every other piece, however, being a little above or below the next piece as shown in Fig. 88. The pieces are two inches thick and the full width of the studding; and in addition to strengthening the wall, they prevent fire or vermin from passing through, and also may be utilized as a nailing surface for any inside finish such as wainscoting or chair rails.

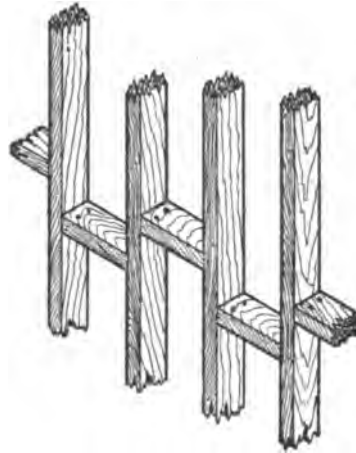


Fig. 88. Horizontal Bridging.

The second method, which we have called diagonal bridging, is more effective in preventing the partition from sagging than is the straight bridging, but both methods may be used with equal propriety. In the diagonal bridging the short pieces are set in diagonally as is shown in Fig. 89, instead of horizontally, between the vertical studding. This method is certainly more scientific than the other, since a continuous truss is formed across the wall.

All partitions should be bridged by one of these methods, at least once in the height of each story, and the bridging pieces should be securely nailed to the vertical studding at both ends. It is customary to specify two tenpenny nails in each end of each piece. Bridging should be placed in the exterior walls as well as in the partition walls; and as a further precaution against fire, it is good practice to lay three or four courses of brickwork, in mortar, on top of the bridging in all walls, to prevent the fire from gaining headway in the wall before burning through and being discovered. This construction is shown in Fig. 90.

Special Partitions. A partition in which there is a sliding door must be made double to provide a space into which the door

may slide when it is open. This is done by building two walls far enough apart to allow the door to slide between them, the studding being of two-by-four or two-by-three stuff, and placed either flatwise or edgewise in the wall. If the studding is placed flatwise in the wall, a thinner wall is possible, but the construction is not so good as in the case where the studs are placed edgewise. If the partition is to support a floor, one wall must be made at least four inches thick to support it, and the studs in the other wall

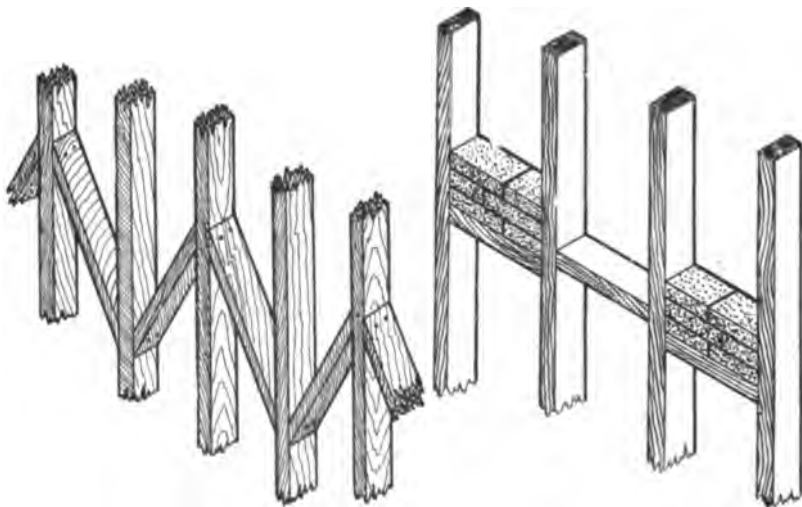


Fig. 89. Diagonal Bridging.

Fig. 90. Brick Work on Bridging.

may then be placed flatwise if desired, and the floor supported entirely on the thick wall. The general arrangement is shown in plan in Fig. 91. It is better to use two-by-three studding set edgewise in each wall so as to make two three-inch walls with space enough between to allow the door to slide freely after the pocket has been lined with sheathing.

A piece of studding A, Fig. 92, should be cut in horizontally between each pair of studs B, eight or ten inches above the top of the door, in order to keep the pocket true and square. The pocket should be lined on the inside with matched sheathing C.

It is well known that ordinary partitions are very good conductors of sound; and in certain cases, as in tenement houses, this is objectionable, so that special construction is required. If two

walls are built entirely separate from each other, and not touching at any place, the transmission of sound is much retarded; and if heavy felt paper or other material is put in between the walls, the partition is made still more nearly sound-proof. In order to decrease the thickness of such a wall as much as possible, the "staggered" partition is used, in which there are two sets of studding, one for each side of the wall, but arranged alternately instead of in pairs as in the double partition. The arrangement is shown in plan in Fig. 93. The two walls are entirely separate from each

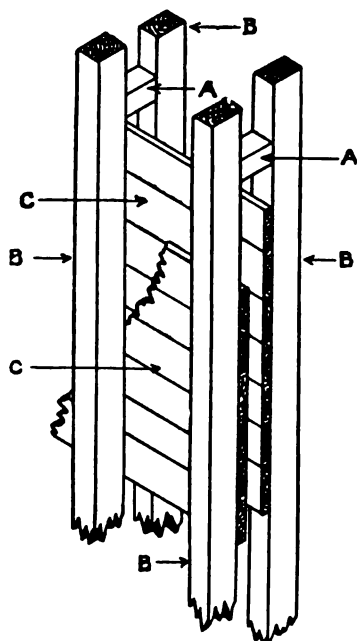


Fig. 92. Double Partition.

other and the felt paper may be worked in between the studs as shown, or the whole space may be packed full of some sound-proof and fireproof material such as mineral wool. There is a so-called "quilting paper" or "sheathing quilt" manufactured from seaweed, which is much used for this purpose. The inside edges of the two



Fig. 91. Double Partition for Sliding Door.



Fig. 93. Sound-proof Partition.

sets of studs are usually placed on a line, making the whole wall eight inches thick where four-inch studding is used, and the studs may be placed about sixteen inches on centers in each wall. Each set of studding should be bridged separately.

Another case where a double wall may be necessary, is where pipes from heaters or from plumbing fixtures are to be carried in the wall. In case of hot pipes, care must be taken to have the space large enough so that the woodwork will not come dangerously near the pipes.

An important matter in connection with the framing of the partitions is the way in which they are supported ; but this involves knowledge of the framing of the floor, and therefore it will be left for the present. It will be taken up after we have considered the floor framing.

Shrinkage and Settlement. An important point which must be considered in connection with the framing of the walls and partitions, is the settlement due to the shrinkage of timber as it seasons after being put in place. Timber always shrinks considerably *across* the grain, but very little in the direction of the grain ; so it is the horizontal members such as the sills, girts, and joists which cause trouble, and not the vertical members such as the posts and studding. Every inch of horizontal timber between the foundation wall or interior pier and the plate is sure to contract a certain amount, and as the walls and partitions are supported on these horizontal members, they too must settle somewhat. If the exterior and interior walls settle by exactly the same amount, no harm will be done, since the floors and ceilings will remain level and true as at first ; but if they settle unequally, all the levels in the building will be disturbed, and the result will be cracking of the plastering, binding of doors and windows, and a general distortion of the whole frame. This must be avoided if possible.

It is evident that one way to prevent unequal settlement, so far at least as it is due to the shrinkage of the timber, is to make the amount of horizontal timber in the exterior and interior walls, equal. Thus, starting at the bottom, we have from the masonry of the foundation wall to the top of the first-floor joists in the outside walls, ten inches, or the depth of the joists themselves, since these rest directly on the top of the wall. In the interior we have, if the joists are framed flush into a girder of equal depth, the same amount, so that here the settlement will be equal. But the studding in the exterior wall rests, not on the top of the joists, but on the top of the six-inch sill, while the interior studding rests on top of the ten-inch girder. Here is an inequality of four inches which must be equalized before the second floor level is reached. If the outer ends of the second-floor joists rest on the top of an eight-inch girt, and the inner ends on a four-inch par-

tition cap, this equalizes the horizontal timber inside and outside, and the second floor is safe against settlement. The same process of equalization may be continued to the top of the building, and if this is done it will go far toward preventing the evils resulting from settlement and shrinkage.

With a balloon frame this cannot be done, because there are no girts in the outside walls, but only ledger-boards which are so fastened that they cannot shrink, while in the interior walls we have still the partition caps. All that can be done in this case is to make the depths of the sills and interior girders as nearly equal as possible, and to make the partition caps as shallow as will be consistent with safety.

THE FLOORS.

After the wall, the next important part of the house frame to be considered is the floors, which are usually framed while the wall is being put up and before it is finished. They must be made not only strong enough to carry any load which may come upon them, but also stiff enough so that they will not vibrate when a person walks across the floor, as is the case in some cheaply-built houses. The floors are formed of girders and beams, or "joists," the girders being large, heavy timbers which support the lighter joists when it is impossible to allow these to span the whole distance between the outside walls.

Girders are generally needed only in the first floor, since in all the other floors the inner ends of the joists may be supported by the partitions in the floor below. They are usually of wood, though it may sometimes be found economical to use steel beams in large buildings. Wrought iron was once used, but steel is now cheaper and has taken the place of wrought iron. It is rarely, however, that this will be found expedient, and hard pine girders will answer very well in most cases. The connections used in the case of steel girders will be explained later. The girders may be of spruce or even of hemlock, but it is hard to get the hemlock in such large sizes as would be required for such girders, and spruce, too, is hardly strong enough for the purpose. Southern pine, therefore, is usually employed for girders in the best work.

The size of the girder depends on the span, or the distance between the supporting walls, and upon the loads which the floor is expected to carry. In general, the size of a beam or girder varies directly as the length of the span, so that if we have two spans, one of which is *twice* as great as the other, the girder for the longer span should be *twice* as strong as the girder for the smaller span. In ordinary houses, however, all the girders are made about eight by twelve inches in section, although sometimes an eight-by-eight timber would suffice, and sometimes perhaps a twelve-inch piece would be required.

It should be remembered in deciding upon the size of this piece, that any girder is increased in strength in direct proportion to the *width* of the timber (that is, a girder 12 inches wide is twice as strong as one 6 inches wide), but in direct proportion also to the *square of the depth* (that is, a girder 12 inches deep is four times as strong as one 6 inches deep). Hence the most eco-

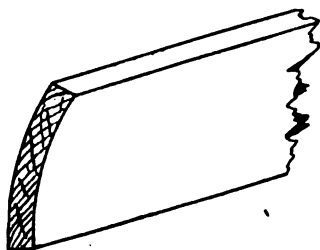


Fig. 94.

nomical girder is one which is deeper than it is wide, such as an eight-by-twelve stick; and the width may be decreased by any amount so long as it is wide enough to provide sufficient stiffness, and the depth is sufficient to enable the piece to carry the load placed upon it. If the piece is made too narrow in proportion to its depth, however, it is likely to fail by "buckling," that is, it would bend as shown in Fig. 94. The width should be at least equal to one-sixth of the depth.

There are at least three ways in which the joists may be supported by the girder. The best but most expensive method is to support the ends of the joists in patent hangers or stirrup irons which connect with the girder. This method is the same as was described for the sill, except that with the girder a double stirrup iron, such as that shown in Fig. 95, may be used. These stirrup-iron hangers are made of wrought iron, two and one-half or three inches wide, and about three-eighths of an inch thick, bent into the required shape. They usually fail by the crushing of the wood of the girders, especially when a single hanger, like that

shown in Fig. 96, is used. Fig. 97 shows a double stirrup-iron hanger in use. Patent hangers as shown in Fig. 98 are by far the best.

If hangers of any kind are used, there will be no cutting of the girder except at the ends where it frames into the sill, and even there a hanger may be used. The girder may be placed so that the joists will be flush with it on top, or so that it is flush

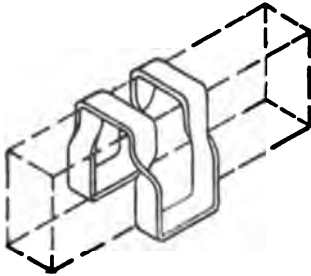


Fig. 95.

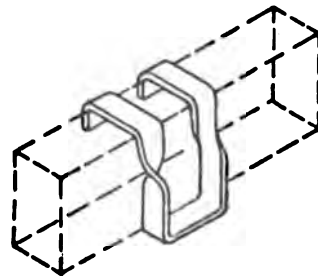


Fig. 96.

with the sill on top. If the joists are flush with the girder on top, and are framed into the sill in the ordinary way, as shown in Fig. 99, the girder cannot be flush on top with the sill; while, on the other hand, if the girder is flush with the sill on top, it cannot at the same time be flush with the joists on top. If joist hangers are used on the girder to support the joists, they will probably be

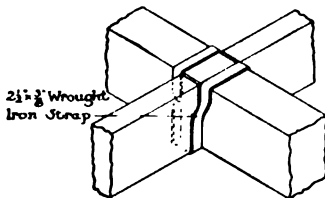


Fig. 97.

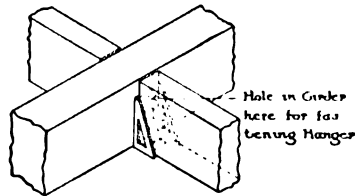


Fig. 98.

used on the sill as well, as explained in connection with the sill; and in this case the girder can be made flush with the sill on top and the joists hung from both girder and sill with hangers, thus bringing both ends of the joist at the same level, as shown in Fig. 100. If the girder is framed into the sill at all, it would almost

always be made flush with the sill on top, and the joists would be arranged so as to be level.

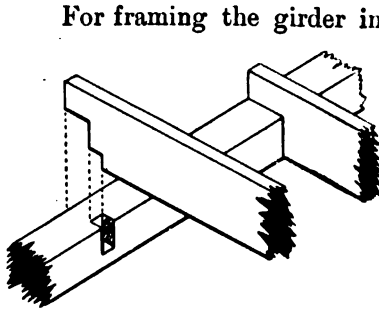


Fig. 99. Framing of Joist into Sill.

For framing the girder into the sill, a tenon-and-tusk joint, as shown in Fig. 101, would be used if the girder is to be flush with the sill on top. Since the girder would in most cases be deeper than the sill, the latter having a depth of only six inches, the wall would necessarily have to be cut away in order to make a place for the girder. This condition is clearly shown in

Fig. 102. The girder itself should not be cut over the wall as shown in Fig. 103, because this greatly weakens the girder. If this method is used, the joists should be framed into

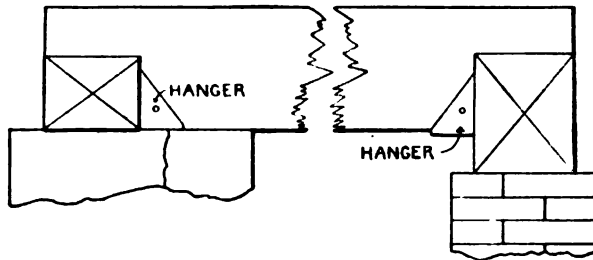


Fig. 100. Use of Hangers.

the girder in the same way as they are framed into the sill, a mortise being cut in the girder and a tenon on the joist. This is called "gaining" and is shown in Fig. 99. The top of the girder thus comes several inches below the top of the floor.

Another method is to make the top of the girder flush with the top of the joists. The joists are then framed into the girder with a tenon-and-tusk joint, as shown in Fig. 101, and the girder is "gained" into the sill as shown in Fig. 99.

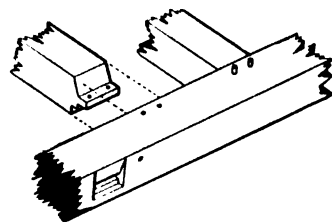


Fig. 101. Framing of Girder into Sill.

Still another method in common use is simply to "size

down" the joists on the girder about one inch, as shown in Fig. 104. In this case, of course, the girder is much lower than the sill, usually so low that it cannot be framed into the sill at all, but

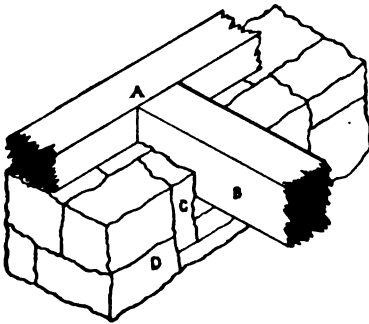


Fig. 102. Framing of Girder into Sill.

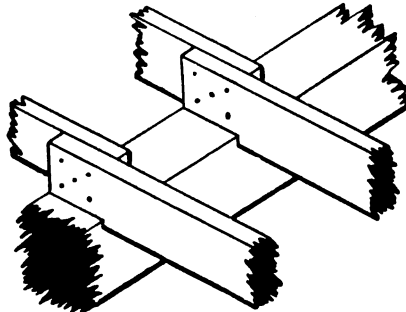


Fig. 104. Joists "Sized Down."

must be supported by the wall independently. Holes are left in the wall where the girders come, the latter being run into the holes, and their ends resting directly on the wall, independent of the sill.

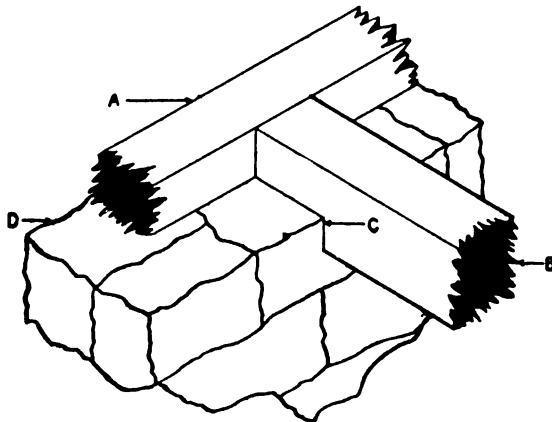


Fig. 103. Framing of Girder into Sill.

This is not very good construction, however, because the floor is not tied together as it is when the girder frames into the sill. The first method is the best and is the one in most common use.

The girders serve to support the partitions as well as to support the floors, and should therefore be designed to come under

the partitions whenever this is possible. When the distance between the outside walls is too great to be spanned by the girder, it is supported on brick piers or posts of hardwood or cast iron in the cellar. Such piers or posts should always be placed wherever girders running in different directions intersect each other. Girders are often supported also on brick partitions built in the cellar.

Joists are the light pieces which make up the body of the floor frame and to which the flooring is nailed. They are almost always made of spruce, although other woods may be used, and may be found more economical in some localities. They are usually two inches thick, but the depth is varied to suit the conditions. Joists as small as two-by-six are sometimes used in very light buildings, but these are too small for any floor. They may sometimes be used for a ceiling where there are no rooms above, and therefore no weight on the floor. A very common size for joists is two-by-eight, and these are probably large enough for any ordinary construction, but joists two-by-ten make a stiffer floor, and are used in all the best work. Occasionally joists as large as two by twelve are used, especially in large city houses, and they make a very stiff floor, but this size is unusual. If a joist deeper than twelve inches is used, the thickness should be increased to two and one-half or three inches, in order to prevent it from failing by buckling as explained in connection with the girders. The size of the joists depends in general upon the span and the spacing.

The usual spacing is sixteen or twenty inches between centers, and sixteen inches makes a better spacing than twenty inches because the joists can then be placed close against the studding in the outside walls and spiked to this studding. It is generally better to use light joists spaced sixteen inches on centers than to use heavier ones spaced twenty inches on centers. The spacing is seldom less than sixteen inches and never more than twenty inches.

Supports for Partitions. In certain parts of the floor frame it may be necessary to double the joists or place two of them very close together in order to support some very heavy concentrated load. This is the case whenever a partition runs parallel with

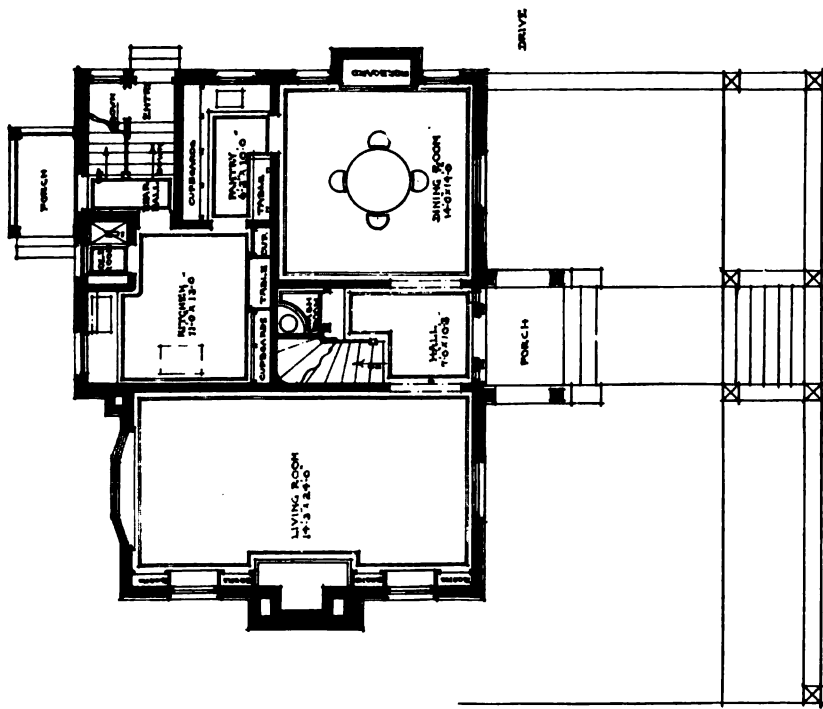




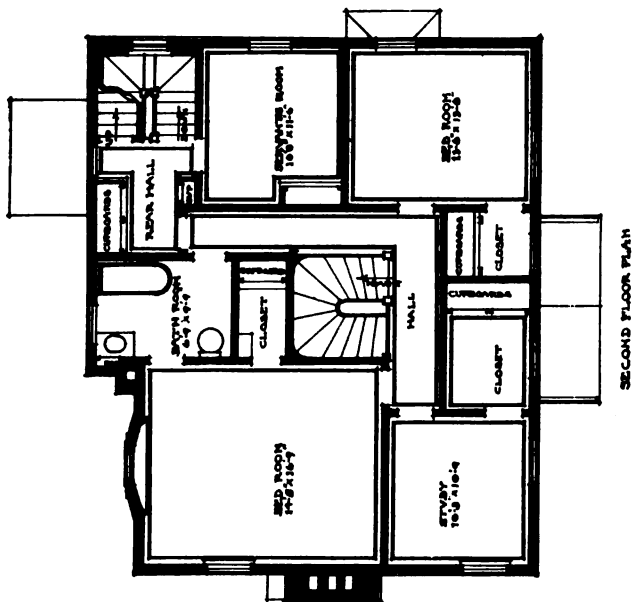
RESIDENCE OF MR. E. S. MEYER, CLEVELAND, OHIO

Waterson & Schneider, Architects, Cleveland, Ohio.

Materials: First Story of Brick; Second Story and Roofs of Shingles. Built in 1904. Cost, \$7,000. For Plans, See Opposite Page.



FIRST-FLOOR-PLAN



SECOND FLOOR PLAN

FIRST AND SECOND STORY PLANS OF RESIDENCE OF MR. E. S. MEYER, CLEVELAND, OHIO
Waterson & Schnelder, Architects, Cleveland, Ohio.



the floor joists, unless it has another partition under it. Such partitions may be supported in several different ways: A very heavy joist, or two joists spiked together, may be placed under the partition, as shown at A in Fig. 105. In this figure, C is the sole, B the under or rough flooring, and D, D, D the studding. This method is objectionable for two reasons: It is often found convenient to run pipes up in the partition, and if the single joist is placed directly under the partition this cannot be done except

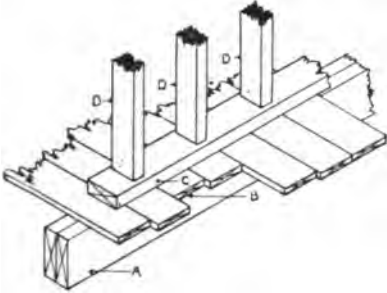


Fig. 105. Joists Supporting Partition.

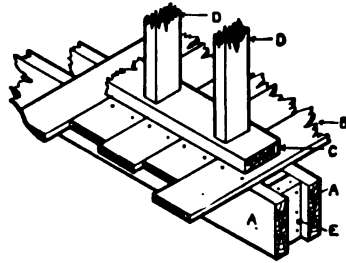


Fig. 106.

by cutting the joist and thus weakening it. Moreover, if the single joist is used, there is no solid nailing for the finished upper flooring, unless the joist is large enough to project beyond the partition studding on each side. The joist is seldom, if ever, large enough for this, and the finished flooring must therefore be nailed only to the under flooring at the end where it butts against the partition, so that a weak, insecure piece of work is the result. This may be seen by referring to the figure.

A much better way is to use two joists far enough apart to project a little on each side of the partition, as shown at A, A in Fig. 106, and thus afford a nailing for the finished flooring. These joists must be large enough to support the weight of the partition without sagging any more than do the other joists of the floor, and therefore joists three or even four inches thick should be used. They should be placed about six or seven inches apart on centers, and plank bridging should be cut in between them at intervals of from fourteen to twenty inches (as shown at E in Fig. 106), in order to stiffen them and make them act together. This plank bridging should be made of pieces of joist two inches

thick and of the same depth as the floor joists, and should be so placed that the grain will in every case be horizontal.

A partition supported as described above is bound to settle somewhat as the ten or more inches of joist beneath it shrinks in

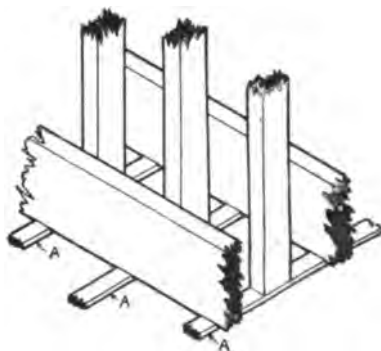


Fig. 107. Partition Supported by Strips.

seasoning, and the settlement may cause cracks in the plastering at the corner between the partition and an outside wall. In order to prevent this settlement, partitions running parallel with the floor joists are often supported on strips which are nailed to the under side of the floor joists, as shown at A in Fig. 107. These strips cannot be allowed to project into the room below, and so they must be made

as thin as possible consistent with safety. Strips of iron plate about one-half inch thick, and wide enough to support the partition studs, are therefore used for this purpose, and are fastened to the joists by means of bolts or lag screws. Partitions which run at right angles to the floor joists can also be supported in this way. If a partition runs at right angles to the joists near the center of their span, the tendency for the joists to sag under it will be very great, and they must be strengthened either by using larger joists, or by placing them closer together. If the span of the floor joists is large

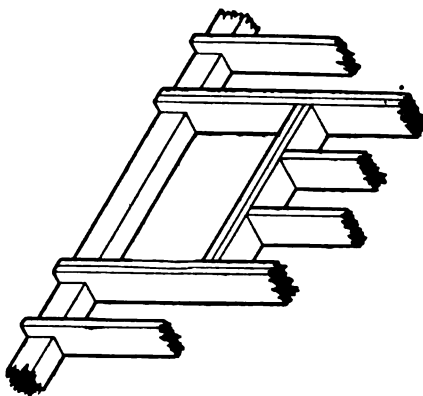


Fig. 108. Headers and Trimmers.

and the partition is a heavy one, it may be necessary to put in a girder running at right angles to the joists to carry the partition. In this case the partition studs will set directly on the girder, which may be a large timber, or in some cases, a steel I-beam.

Headers and Trimmers. Another case where a girder may be necessary in a floor above the first, is where an opening is to be left in the floor for a chimney or for a stair well. The timbers on each side of such an opening are called "trimmers," and must be made heavier than the ordinary joists; while a piece called a "header" must be framed in between them to receive the ends of the joists, as shown in Fig. 108.

The trimmers may be made by simply doubling up the floor joists on each side of the opening, or, if necessary, I-beams or heavy wooden girders may be used. In most cases these trimmers may be built up by spiking together two or three joists, and the header may be made in the same way.

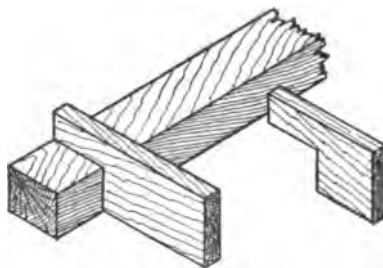


Fig. 109. Connection of Joist to Sill.

Joist Connections. Joists are also "gained" into the sill as shown in Fig. 56, in which case a mortise is cut in the sill and a corresponding tenon is cut in the end of the joist. The mortise was illustrated and described in connection with the sill, while the end of the joist is cut as shown in Fig. 56, the tenon being about four inches deep and gained into the sill about two inches. This brings the bottom of the joist flush with the bottom of the sill, and the top of the joist somewhat above the top of the sill,



Fig. 110.

according to the depth of the joist. The top of a ten-inch joist would come four inches above the top of a six-inch sill, and the joist would rest partly on the masonry wall as shown in Fig. 100, thus relieving the connection of a part of the stress due to the weight of the loaded joist. A common but very bad method of framing the joist to the sill is simply to "cut it over" the sill without mortising the latter, as shown in Fig. 109. This does not make a strong connection even when the joist rests partly on the masonry wall; and if it is not so supported it is almost sure to fail by splitting, as shown in Fig. 110, under a very small loading. In fact, it would be much stronger if the joist were turned upside

down. Frequently the joist is cut as shown in Fig. 111, where the tenon is sunk into a mortise cut in the sill, thus bringing the top of the joist flush with the top of the sill; but in this case the bottom of the joist will almost invariably drop below the bottom of the sill, and the wall must be cut away to make room for it, as shown in Fig. 102. It is also weak in the same way as is the connection shown in Fig. 110.

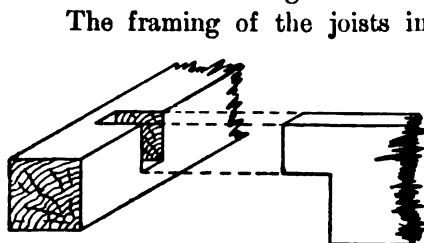


Fig. 111. Joist Mortised into Sill.

The framing of the joists into the girders may be accomplished in several different ways, according to the position of the girder. This placing of the girder is quite an important point. The top of the floor, on which rest the sole-pieces of the cross-partitions, must remain always true and level, that is, the outside ends of the joists must be at the same level as the inside ends. Otherwise the doors in the cross-partitions will not fit their frames, and cannot be opened or shut, and the plastering is almost sure to crack. Both ends of the joists will sink somewhat, on account of the shrinkage of the timber in seasoning, and the only way to make sure that the shrinkage at the two ends will be the same is to see that there is the same amount of *horizontal* timber at each end between the top of the floor and the solid masonry. This is because timber shrinks very much *across* the grain, but almost not at all *along* the grain. If the joist

is framed properly into the sill, so that it is flush on the bottom with the sill, we have at the outer end of the joist a depth of horizontal timber equal to the depth of the joist

itself, as shown in Fig. 100; and in order to have the same depth of timber at the inside, the bottom of the joist must be flush with the bottom of the girder, which usually rests on brick piers. Of course the top of the girder must not in any case come above the tops of the floor joists; therefore, in general, the

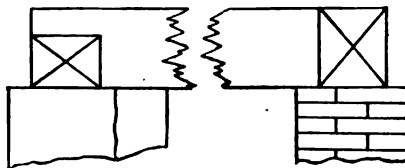


Fig. 112. Joist Framed into Girder.

girder must be equal in depth to the floor joists and flush with these joists on top and bottom, as shown in Fig. 112. This method is not always followed, however, in spite of its evident superiority; and the girder is often sunk several inches below the tops of the floor joists, as shown in Fig. 100, or even in some cases very much below, as shown in Fig. 113. Both of these methods cause an unsightly projection below the ceiling of the cellar. Where the joists are brought flush with the girder top and bottom, they may be framed into it with a tenon-and-tusk joint, the joists being cut as shown in Fig. 101, with a tenon as there shown, and a hole bored through the tenon to receive a pin to hold the joist in place.

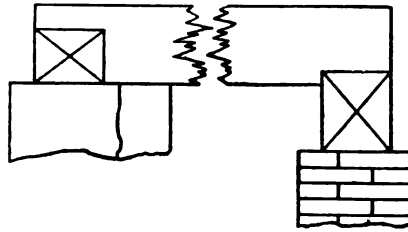


Fig. 113. Joist Sized Down on Girder.

Other methods of framing tenon-and-tusk joints are shown in Figs. 33, 34, and 35, and also a double-tenon joint in Fig. 36, which might be used in this case, although it is much inferior to the tenon-and-tusk joint. Two joists framing into a girder from opposite sides should be fastened strongly together, either by an iron strip passing over the top of the girder and secured to each joist, as shown in Fig. 114, or by means of a "dog" of round bar iron, which is bent at

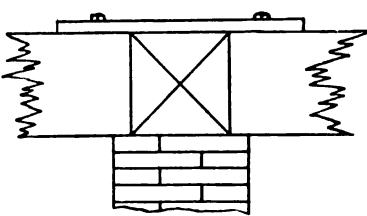


Fig. 114. Use of Straps and Dogs.

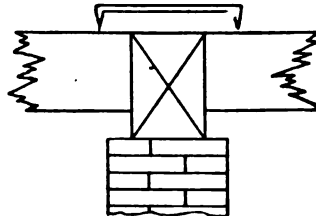


Fig. 115.

the ends and sharpened so that it may be driven down into the abutting ends of the joists, as shown in Fig. 115. These bars should be used at every fifth or sixth joist, to form a series of continuous lines across the building from sill to sill.

If the girder is sunk a little below the tops of the joists, these may be gained into it in the same way as they are gained

into the sill. In this case joists should be arranged as shown in Fig. 116, so that they will not conflict with one another; and the two adjacent joists may be spiked together, thus giving additional stiffness to the floor. If the tenon-and-tusk connection is used, the joists may be arranged exactly opposite each other, provided that the girder is sufficiently wide, but it is always much better to

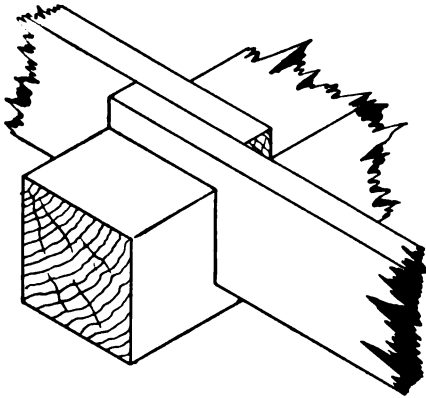


Fig. 116. Joists Framing over Girder.

arrange them as shown in Fig. 117, even in this case. The tenon may then be carried clear through the girder and fastened by a dowel, as shown. Very rarely a simple double-tenon joint, such as that shown in Fig. 36, might be used, but it is much inferior to either the galling or the tenon-and-tusk joint.

If the girder is sunk very much below the tops of the joists, as in Fig. 113, these will usually rest on top of it and be fastened by spikes only, or will be "sized down" upon it about one inch, as shown. There is no mortising of the girder in either case. Joists are also thus sized down upon the girts and partition caps, and are notched over the ledger-boards as shown in Fig. 67. In cutting the joists for sizing and notching, the measurements should be taken in every case from the *top* of the joists, since they may not all be of exactly the same depth, and the tops must all be on a level after they are in place. This is really the only reason why the joists should be sized down at all, because otherwise they might simply rest upon the top of the girder, or girt, and be fastened by nailing.

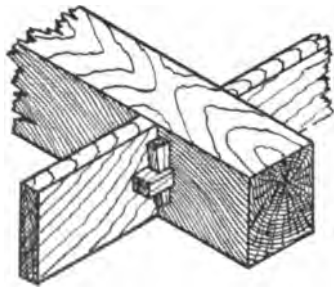


Fig. 117.

Connection to Brick Wall. When a joist or girder is supported at either end on a brick wall, there will either be a hole

left in the wall to receive it, or the wall will be corbeled out to form a seat for the beam. If the beam enters the wall the end should be cut as shown in Fig. 118, so that in case of the failure of the beam from overloading or from fire, it may fall out without injuring the wall. Every fifth or sixth joist is held in place by an

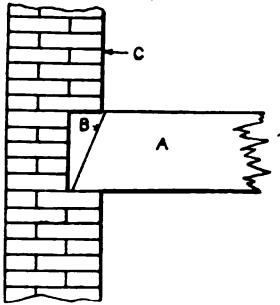


Fig. 118. Joist Supported by Brick Wall.

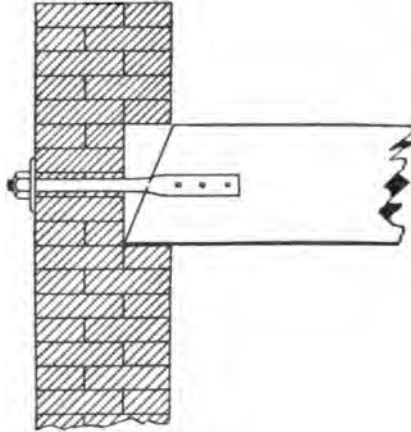


Fig. 119. Use of Anchor.

anchor (as shown in Fig. 119), of which there are several kinds on the market. Fig. 120 shows the result when a beam which is cut off square on the end, falls out of the wall.

There must always be left around the end of a beam which is in the wall a sufficient space to allow for proper ventilation to prevent dry rot, and the end should always be well painted to keep out the moisture. Patent wall-hangers and box anchors are often used to support the ends of joists in brick buildings, but only in case of heavy floors.

The floor framing in a brick building is the same as that in a building of wood except that there is no girt to receive the ends of the floor boards, so that

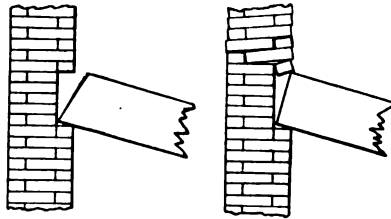


Fig. 120.

a joist must be placed close against the inside of the wall all around the building to give a firm nailing for the flooring.

Crowning. In any floor, whether in a wood or a brick building, if the span of the floor joists is very considerable so that

there is any chance for deflection they must be "crowned" in order to offset the effect of such deflection. The operation called "crowning" consists in shaping the top of each joist to a slight curve, as shown in Fig. 121 B, so that it is an inch or so higher in the middle than it is at the ends. As the joist sags or deflects, the top becomes level while the convexity will show itself in the bottom as shown in Fig. 121 A. Joists need not be crowned unless the span is quite large and the loads heavy enough to cause a deflection of an inch or more at the center of the joist.

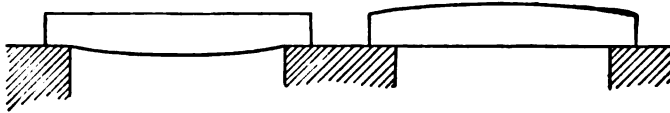


Fig. 121 A. Crowning. Fig. 121 B.

Bridging. Floor frames are "bridged" in much the same way as was described for the walls, and for much the same purpose, namely, to stiffen the floor frame, to prevent unequal deflection of the joists, and to enable an overloaded joist to get some assistance from the pieces on either side of it. Bridging is of two kinds, "plank bridging" and "cross bridging," of which the first

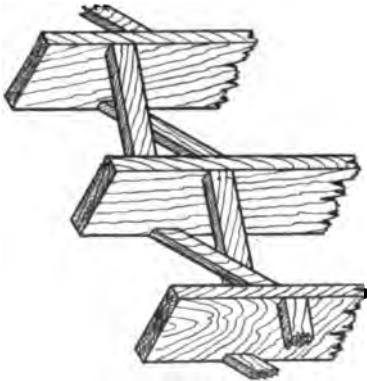


Fig. 122. Diagonal Bridging.

has already been shown in connection with the partition supports. Plank bridging is not very effective for stiffening the floor, and cross bridging is always preferred. This bridging is somewhat like the diagonal bridging used in the walls, and consists of pieces of scantling, usually one-by-three or two-by-three in size, cut in diagonally between the floor joists. Each piece is nailed to the top of one joist and to the bottom of the next; and two pieces

which cross each other are set close together between the same two joists, forming a sort of St. Andrew's cross, whence we get the name "cross bridging," or "herring-bone bridging" as it is sometimes called. The arrangement is shown in Fig. 122, and the bridging should be placed in straight lines at intervals of eight or

ten feet across the whole length of the floor. Each piece should be well nailed with two eightpenny or tenpenny nails in each end. If this is well done there will be formed a kind of continuous truss across the whole length of the floor which will prevent any overloaded joist from sagging below the others, and which will greatly stiffen the whole floor so as to prevent any vibration. The bridging, however, adds nothing to the strength of the floor.

Porch Floors. A word might appropriately be inserted at this point in regard to the floors of piazzas and porches. These may be supported either on brick piers or on wooden posts, but preferably on piers, as these are much more durable than posts. If piers are used, a sill, usually four by six in size, should be laid on the piers all around, and light girders should be inserted between the piers and the wall of the house in order to divide the floor area into two or three panels. The joists may then be framed parallel to the walls of the house, and the floor boards laid at right angles to these walls. The whole frame should be so constructed that it will pitch outward, away from the house at the rate of one inch in five or six feet, thus bringing the outside edge lower than the inside edge and giving an opportunity for the water to drain off.

Stairs. The stairs are built on frames called "stringers" or "carriages," which may be considered as a part of the floor framing. They consist of pieces

of plank two or three inches thick and twelve or more inches wide, which are cut to form the steps of the stairs and which are then set up in place. There are usually three of these stringers under each flight of stairs, one at each side and a third in the center, and they are fastened at the bottom to the floor and at the top to the joists which form the stair well. This subject will be taken up more fully under "Stair Building."

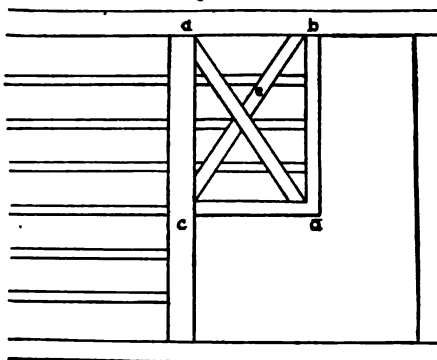
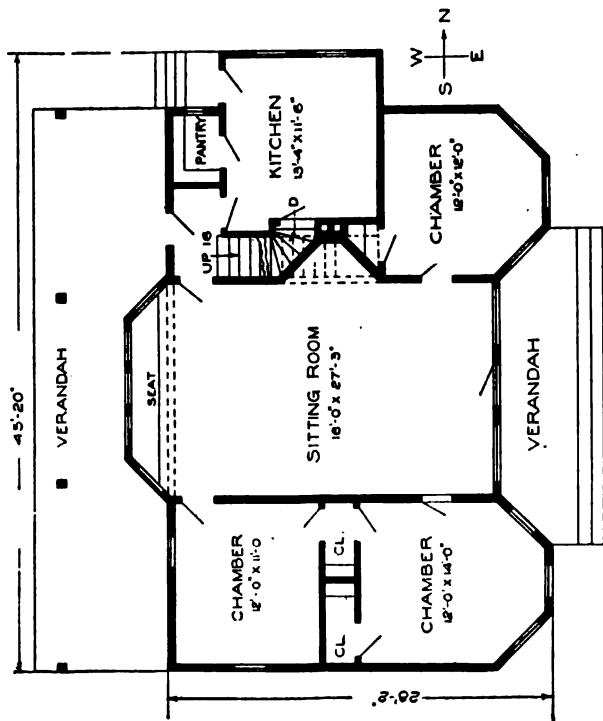


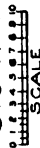
Fig. 123. Support of Corner.

Unsupported Corners. An interesting place in a floor framing plan is where we have a corner without any support beneath it, as at the corner *a* in Fig. 123. This corner must be supported from the three points *b*, *c*, and *d*, and the figure shows how this is accomplished. A piece of timber *e* is placed across from *b* to *c*, and another piece starts from *d* and rests on the piece *b c*, projecting beyond it to the corner *a*. This furnishes a sufficiently strong support for the corner.

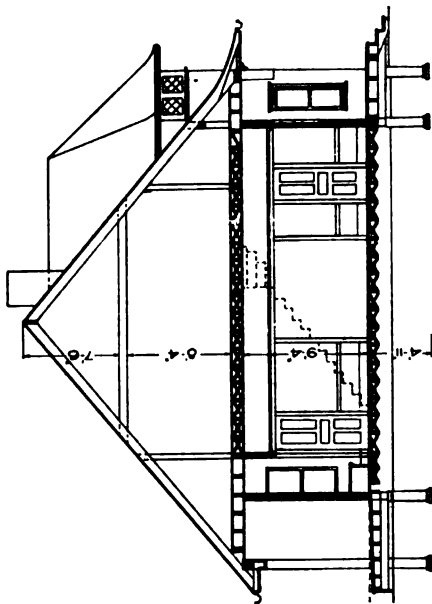




FIRST STORY PLAN



SECTION



SUMMER HOME IN MICHIGAN, OF W. CARBYS ZIMMERMAN, ARCHITECT, CHICAGO, ILL.

House was Built in 1904, at a Time when the Prices of Material and Labor were at their Lowest. It Cost, without Heating and Plumbing, \$650. Economy is Greatly Due to the Simplicity of the Roof Construction.

CARPENTRY.

PART II.

THE ROOF.

IN Part I we saw that the subject of framing could be considered under three distinct headings; the framing of the wall, the framing of the floor, and the framing of the roof. So far we have discussed only the framing for the wall and that for the floor, so we will now take up the framing for the roof.

The roof framing is one of the most difficult problems with which the carpenter has to deal, not because of the number of complicated details, for there are few of these involved, but on account of the many different bevels which must be cut in order to make the rafters frame into one another correctly.

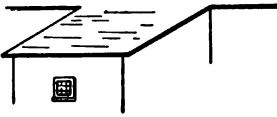


Fig. 124. Lean-to Roof.

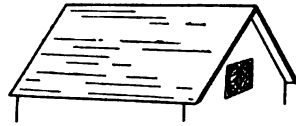


Fig. 125. Pitch or Gable Roof.

Varieties of Roofs. There are many varieties of roofs, ranging all the way from the simple pitch roof to the most complicated combination of hips and valleys; but they are all developments of a few simple forms.

The *lean-to* roof is the simplest of all and is usually employed for small sheds, piazzas, porches, ells, and in many other situations. It is shown in Fig. 124. Its characteristic is that it has but one slope, which renders it unsightly and unfit for use on any important structure.

The *pitch*, or *gable*, roof is very common, and is also quite simple in form. It has two slopes, meeting at the center, or "ridge," and forming a "gable" at each end of the building. This form of roof is shown in Fig. 125. It is popular on account of the ease with which it can be constructed. It may be used in combination with roofs of other kinds.

The *gambrel* roof is somewhat like the gable roof, and is probably a development of it; but the gable is not triangular in shape, as is shown in Fig. 126. Gambrel roofs may be seen on many old houses, built in Colonial days, and they have lately come again into use.

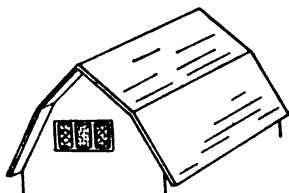


Fig. 126. Gambrel Roof.

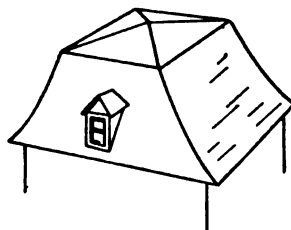


Fig. 127. Mansard Roof.

The *mansard* roof, called by the name of the architect who introduced it, is like the gable roof except that it slopes very steeply from *each* wall toward the center, instead of from two opposite walls only, and it has a nearly flat "deck" on top. It bears a close relation to the so-called *hip* roof. It is shown in Fig. 127.

The *hip* roof mentioned above also slopes from all four walls toward the center, but not so steeply as does the mansard roof.

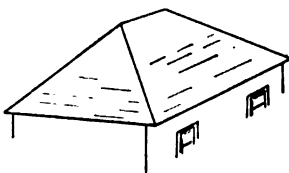


Fig. 128. Hip Roof.

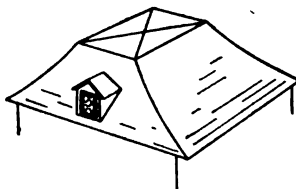


Fig. 129. Hip Roof with Deck.

It is usually brought to a point or a ridge at the top, as in Fig. 128, but sometimes it is finished with a small flat deck, as in Fig. 129.

In Fig. 130 is shown a very simple form of what is known as the *hip-and-valley* roof. It is a combination of two simple pitch roofs which intersect each other at right angles. In the figure both ridges are shown at the same height, but they are not always built in this way. Either ridge may rise above the other, and the two roofs may have the same pitch, or different pitches.

If the ridge of the secondary roof rises above the ridge of the main roof, the end which projects above the main ridge is usually finished with a small gable, as shown in Fig. 131. This arrangement does not make a pleasing appearance, however, and should be avoided if possible.

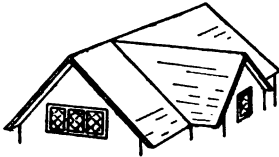


Fig. 130. Hip and Valley Roof.

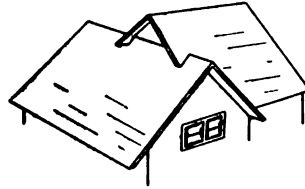


Fig. 131. Hip and Valley Roof.

The Rafters. In all roofs the pieces which make up the main body of the frame are the rafters. They are for the roof what the joists are for the floor and what the studs are for the wall. They are inclined members, spaced from sixteen to twenty inches apart on centers, which rest at the bottom on the plate, and are fastened at the top in various ways according to the form of the roof. The plate, therefore, forms the connecting link between the wall and the roof, and is really a part of both. Rafters are sometimes made as small as two by six, but this is allowable only in the very lightest work. The size of rafters for common dwelling houses is usually two by eight. In some cases it may be found necessary to use rafters as large as two by ten for heavy work.

The connection of the rafters to the wall is the same in all the types of roofs described. They are not framed into the plate, but

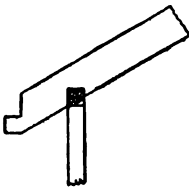


Fig. 132. Rafters Extended over Plate.

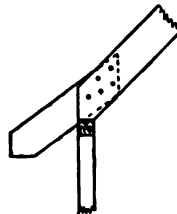


Fig. 133. Eaves Formed with Separate Piece.

are simply spiked to it. Usually they extend out beyond the wall so as to form the eaves, as shown in Fig. 132, and they are then cut over the plate and allowed to continue beyond. Sometimes

the rafter itself is not extended beyond the plate, but is cut off at that point, and a separate piece is nailed against it to form the eaves, as shown in Fig. 133. This piece does not always continue in the same line with the rafter, but may make an angle with it, as shown in the figure, so as to give a break in the roof line.

There are four different kinds of rafters used in framing roofs, all of which may sometimes be found in a single roof, if it is of complicated design, while ordinary roofs may be framed with only the more simple forms. In Fig. 134 is shown the framing plan of a roof in which all four kinds of rafters are to be found. *a a a* are *common* rafters which extend clear up from the plate to the ridge and which are not connected with any of the other rafters. *b b b* are *jack* rafters which are shorter than the common rafters and which do not extend from the plate to the ridge, but

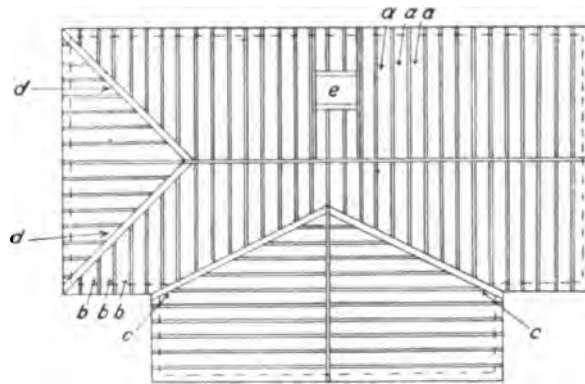
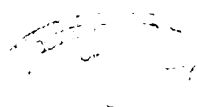


Fig. 134. Framing Plan of Roof.

are connected at one end to a *hip* or *valley* rafter. *c c* are the valley rafters, which are needed at every corner between the main building and an ell or other projection, while the *hip* rafters are found at every outside corner. At the points where the valley rafters are situated there are troughs or valleys formed by the roof surfaces—as these pitch downwards on both sides toward the valley rafter—while at the outside corners, where the hip rafters are found, the roof surfaces pitch upward on each side to the hip rafter. This may be seen by looking at any hip and valley roof as actually constructed.

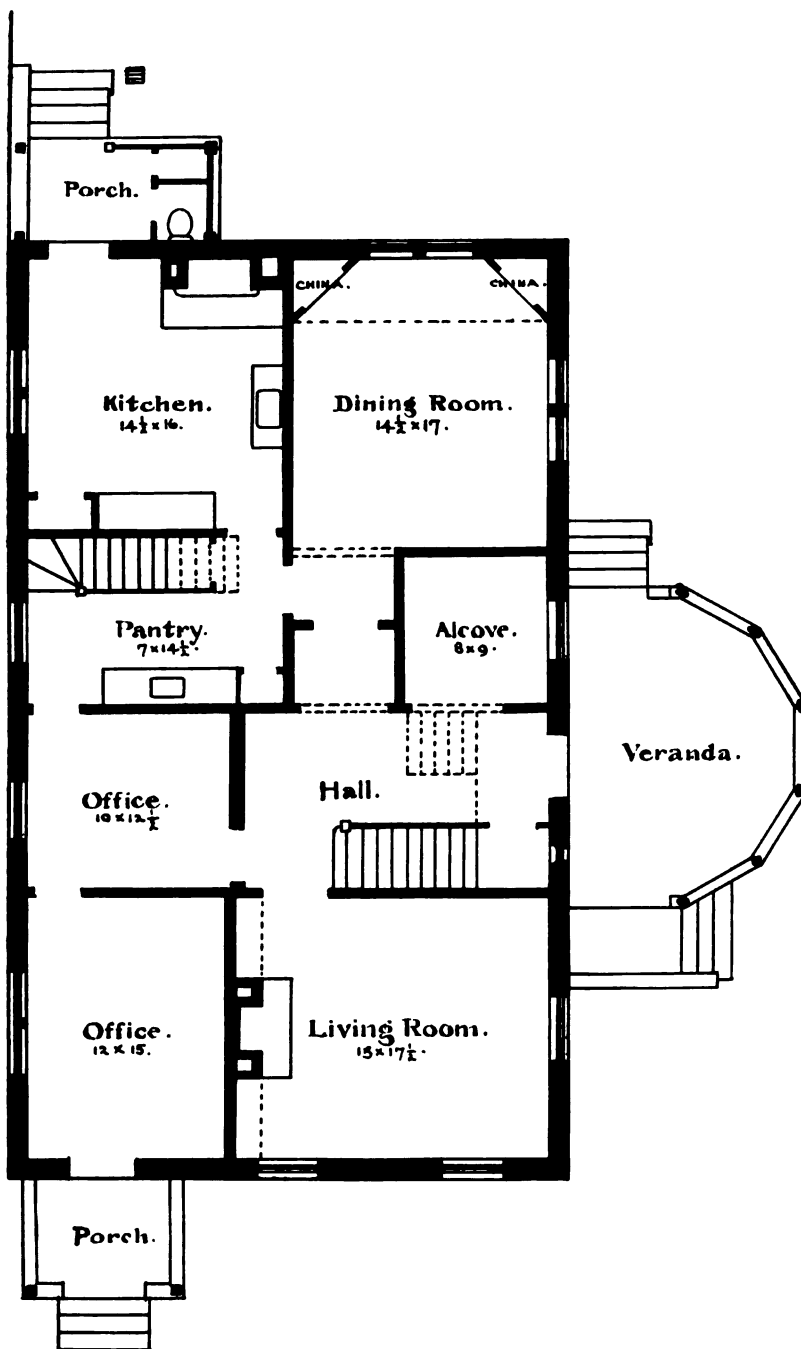




RESIDENCE OF DR. FOLTZ, CHESTNUT HILL, PHILADELPHIA, PA.

George T. Pearson, Architect, Philadelphia, Pa.

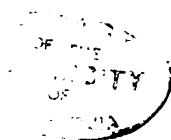
Planned to Meet the Requirements of a Physician's Residence and Office. The Exterior Treatment, as Indicated by the Timber Framing, Finishing of Roof, etc., is in the Dutch Style, the Base being Stone, Then a Band of Flemish-Bond, Dark Header Brickwork, and, above that, Rough Brick Walls Stuccoed. Plan Shown on Opposite Page.



PLAN OF RESIDENCE OF DR. FOLTZ, CHESTNUT HILL, PHILADELPHIA, PA.

George T. Pearson, Architect, Philadelphia, Pa.

Interior Woodwork is Treated in Dutch Style, of Dark Chestnut in Hall and Dining Room, and Painted Wood in Living Room and Second Story. Ceilings of First Story Have Beams Exposed, and Finished in Places with Quaint Carvings and Scroll Decoration Characteristic of the Dutch Style. Exterior View Shown on Opposite Page.



In pitch or gable roofs there are no hip rafters, but there may be valley rafters and jack rafters, while common rafters are to be found in all roofs.

The Ridge. In the lean-to roof the rafters rest at the top against the wall of the building of which the ell, or porch, is a part; and the framing of the roof consists simply in setting them up and securing them in place with spikes or nails. The pitch roof, however, is formed on the principle that two pieces which are inclined against each other will hold each other up, and so the rafters must rest against each other at the top in pairs, as shown in Fig. 135. It is customary to insert between the rafters, at the top, a piece of board about one inch in thickness and deep enough

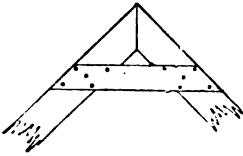


Fig. 135. Top of Rafters.

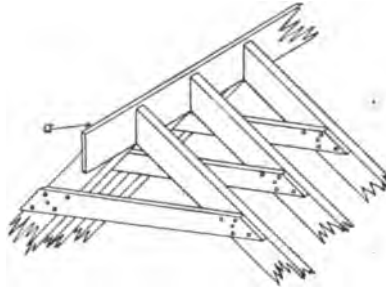


Fig. 136. Ridge Pole Between Tops of Rafters.

to receive the whole depth of the rafter, as shown at *a* in Fig. 136. This piece of board is called the *ridge* or the *ridge pole* and extends the whole length of the roof. It serves to keep the rafters from falling sideways, and keeps the roof frame in place until the roof boarding is on. It is sometimes extended above the rafters, and forms a center for some form of metal finish for the ridge, as shown in Fig. 137.

Interior Supports. In small roofs which have to cover only narrow buildings and in which the length of the rafters is small, there is no necessity for any interior support. When the rafters have been cut to the correct length, set up against the ridge, and secured in place, the framing is complete. In roofs of large span, however, the rafters would sag in the middle if they were not strengthened in some way, so it is customary to put a vertical support under them. This support may be formed by placing a piece

of studding under each rafter, somewhere between the plate and the ridge, and if this is done very much lighter rafters can be used than would otherwise be considered safe. It is claimed by some that it is cheaper to do this than to use the heavy rafters. A more common way of supporting the long rafters is to use fewer upright pieces and to place a horizontal piece *a* on top of them, running the whole length of the building and supporting each rafter. This is shown in Fig. 138. An upright piece *b* should be placed under every sixth or seventh rafter in order to give the necessary stiffness to the whole construction. For the uprights, pieces of ordinary studding, two by four inches or two by three inches in size, may be used. When there is to be a finished attic in the

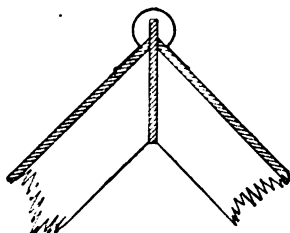


Fig. 137. Cross Section at Ridge Pole.

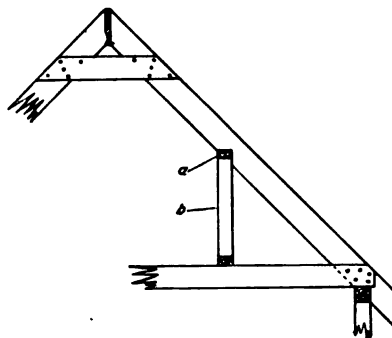


Fig. 138. Support for Long Rafters.

building these upright studs may be made to form the side walls of the attic rooms, and must then be spaced sixteen inches, or thereabouts, on centers. In this case a piece of studding could be placed under each rafter. Such walls are called *dwarf walls*.

Another form of interior support is the *collar beam* or *tie beam*. This is a piece of timber which extends between the rafters on opposite sides of the roof and ties them together, as shown at *a* in Fig. 139. It may be a piece of board about one inch thick and eight or ten inches wide, which is nailed onto the side of the rafter at each end. It is placed as near the center of the rafter as may be practicable, and in the case where a finished attic is required it forms the support for the ceiling. For this reason it must be at a considerable height from the attic floor, and

cannot always be placed very near the center of the rafter. The important point is to see that it is well nailed at each end.

A very interesting form of gable roof is that in which there is a double gable with a valley between, which forms the roof of

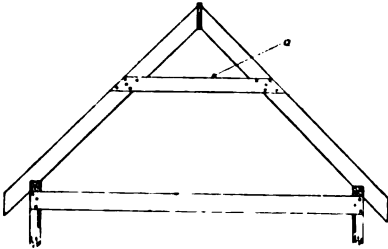


Fig. 130. Tie Beam Support for Rafters.

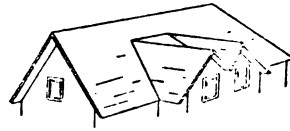


Fig. 140. Pitch Roof with Double Gable.

the ell, the main roof being a simple pitch roof. This is shown in Fig. 140. Fig. 141 shows how such a roof may be framed. The piece *a* is placed in the wall and supported by the strutting and serves as a plate to receive the ends of the pieces *b*, which are val-

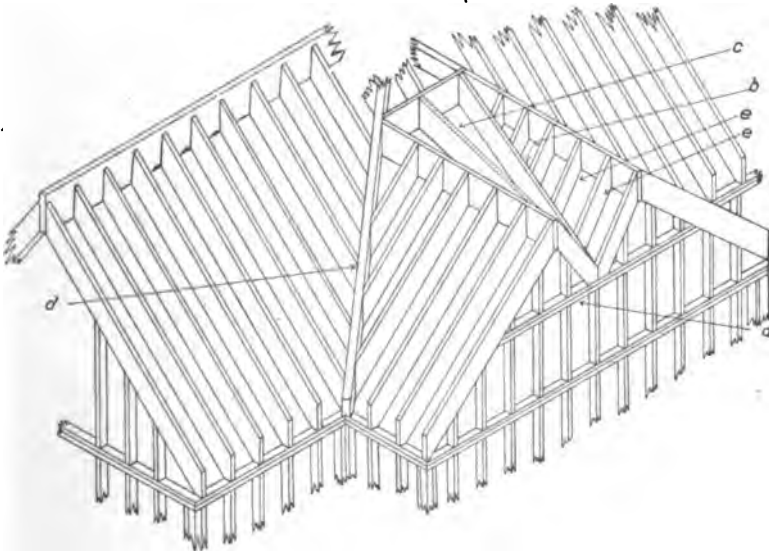


Fig. 141. Framing for Double Gable.

ley rafters. These, together with the piece *c*, form the framing for the shallow valley between the two gables. The valley rafters on the outside, marked *d* in the figure, are similar to those used

in the case of a single gable. The pieces *e e* are jack rafters and are very short. This form of roof is not common, but in some places it gives a good effect.

Framing of Gambrel Roof. A gambrel roof is framed in very much the same way as is a pitch or a hip roof. The slope of the roof, however, is broken at a point about midway between the plate and the ridge. The part of the roof above this break makes an angle with the horizontal plane of less than forty-five degrees, usually, while the portion below the break make an angle with the horizontal plane greater than forty-five degrees. This is shown in Fig. 126.

The lower slope may almost be considered a part of the wall, and at the point where the slope changes there is a secondary plate from which the upper slope starts, as shown at *a* in Fig. 142. The secondary plate may be utilized as a support for the ends of the ceiling joists *b*, which should also be securely spiked to the rafters, as shown in the figure. The rafters *c*, forming the upper slope, must be cut over the plate *a*, and firmly spiked to it, while at the top they rest against a ridge board *d*. The rafters *e*, forming the lower slope, are cut out at the top so as to form a seat

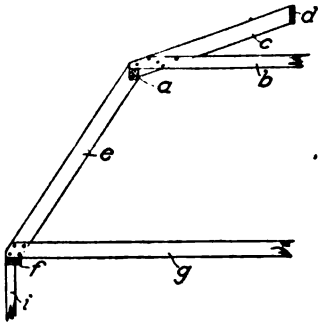


Fig. 142. Framing of Gambrel Roof.

for the plate *a*, and must be very securely fastened at the bottom to the main wall plate *f*. It is an excellent plan to have the floor joists *g* spiked to the lower rafters, so as to act like tie beams across the building and to counteract the outward thrust of the rafters. Sometimes these floor joists are dropped below the wall plate *f*, and are supported on a ledger-board notched into the wall studding *i*. This construction is not so good as that shown in the figure, because the joist is not so effective as a tie across the building. If it is employed, the floor joists must be securely nailed to the wall studding *i*, and they must not in any case be dropped more than two or three feet below the plate. The plate must always be firmly nailed to each stud to prevent it from being forced outward as it receives the thrust from the rafters *e*.

A good rule for determining the point at which to place the secondary plate *a*, and for determining the general shape of the roof, is illustrated in Fig. 143. Let the points *a* and *b* represent the main plates on each side of the building. Draw a line *a b* between them and bisect this line at *c*. With *c* as a center and *c a* as a radius describe the semicircle *a d e f b*.

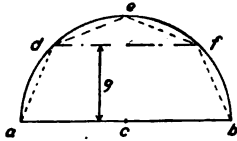


Fig. 143. Laying out Shape of Roof.

At any distance *g* above *a b* draw a line *d f* parallel to *a b*, cutting the semicircle at the points *d* and *f*. Also bisect the arc at *e*. Then by joining the points *a d e f* and *b* by straight lines as shown, we will have the outline of a gambrel roof. The proportions of the

roof may be varied by varying the distance *g*.

Gambrel roofs are not very strong unless they are stiffened by cross partitions in the attic stories, and these should be provided whenever it is possible. No gambrel roof, unless it is well braced, should be used on a building which is exposed to high winds, or which is likely to receive a heavy weight of snow.

Framing of Mansard Roof. A mansard roof is framed in very much the same way as is a gambrel roof, as may be seen in Fig. 144. Resting on the main wall plate *a* we have a piece *b* which is inclined slightly inward, and which supports at its upper end a secondary plate *c*. On the plate *c* rests the outer end of the deck rafter *d* which is nearly horizontal. The piece *b* is a piece of studding, two by four inches to four by six inches in size, depending upon the size of the roof. It supports the whole weight from the rafters, carrying it to the main wall plate and thence into the walls of the building. This member should always be straight, and the curved shape which is usual on mansard roofs is obtained by the use of the furring piece *e*. This piece is nailed to the upright member *b* at the top, and at the bottom it is secured to the lookout *f* which also forms a support for the projecting cornice. The floor joist *g* is supported on a ledger-board

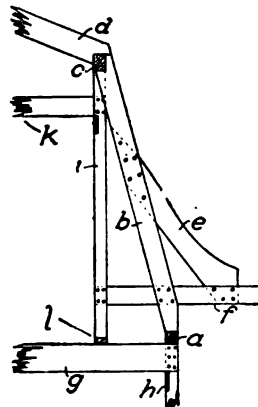


Fig. 144. Framing of Mansard Roof.

h, or it may rest directly on the plate *a*. The piece of studding *i* is merely a furring stud to form the wall of the attic room. It may be omitted entirely if desired, or if the attics are to be unfinished. The ceiling joist *k* may be supported on a ledger-board as shown, or may be simply spiked to the studding *i* or to the upright *b*. The studding *i* may rest directly on the floor joists *g* with a sole piece *l* at the bottom, as shown. The plate *c* should be of a good size, at least four by six inches, and should not be placed more than two or three feet above the ceiling joists *k*. The ceiling joists act as ties across the building and prevent the plates *c* from spreading apart, as they receive the thrust from the rafters *d*. For this reason it is better to have the ceiling joist *k* fastened to the upright *b* rather than to the furring stud *i*.

Dormer Windows. In Figs. 145 and 146 are shown what are known as *dormer* windows, this name being applied to all windows in the roofs of buildings, whatever may be their size or



Fig. 145. Dormer Window.

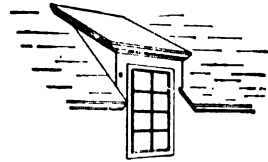


Fig. 146. Dormer Window.

shape. The figures show two different kinds of dormers which are in general use, the one shown in Fig. 145 resting entirely on the roof, while the one shown in Fig. 146 is merely a continuation of the wall of the building above the line of the eaves. The second type is often seen on low buildings, only one story in height, while the other kind is employed on larger structures.

In order to construct a dormer window an opening must be made in the roof surface, and the window must be built up over the opening. Headers are framed in between two of the rafters as shown at *a* and *b* in Fig. 147, and thus a rectangular opening is formed in the roof frame. The rafters *c* and *d*, which form the sides of the opening, are called *trimmers* and should be much stronger than the common rafters. Usually the trimmers are

made by doubling the ordinary rafters. The headers receive the ends of the rafters which are cut by the opening, and must be large enough to carry the weight which comes from them beside supporting the walls of the dormer. Timbers four by eight inches to six by ten inches, according to the size of the dormer, are usually large enough for the headers and often smaller timbers may be safely used.

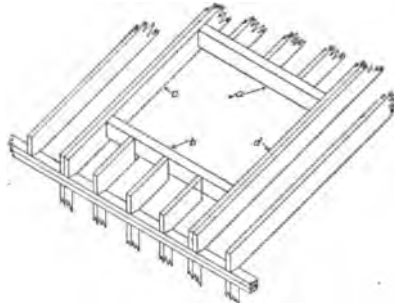


Fig. 147. Headers for Dormer Windows.

The headers are shown in section at *a* and *b* in Fig. 148, and it will be noticed that they are not put in in exactly the same way. The piece at the top *a* is so placed that its longer dimension is at right angles to the plane of the roof, while the piece at the bottom *b* has its longer dimension vertical. In the case shown in Fig. 146, where the front wall of the dormer is merely an extension of the main wall of the

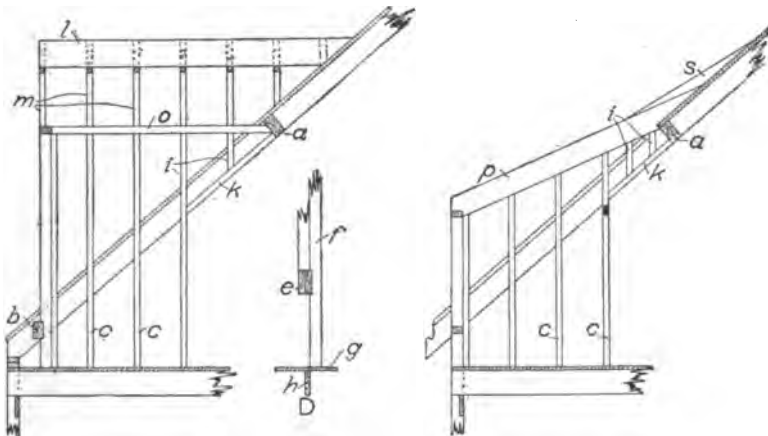


Fig. 148. Longitudinal Sections Through Dormer Windows.

building, there is no need of the lower header *b*, the main wall plate taking its place and supporting the studding for the front wall of the dormer, as shown at the right hand side of Fig. 148.

Fig. 148 shows sections taken through two dormers of the types mentioned above, parallel to the direction of the main rafters

and at right angles to the main wall plate of the building. At the left is a section taken through the type of dormer shown in Fig. 145, while at the right a section of the other type is shown. The studs *c c*, which form the side walls of the dormer, are notched over the trimmer rafters and roof boarding about one inch, and allowed to continue downward to the attic floor. This is shown at *D*. At *e* is a section of the trimmer rafter, *f* is the wall stud, *g* is the attic floor boarding, and *h* is a section of one of the attic floor joists. The studs *c* are in line with the studs forming the side walls of the attic room, so the studs *i* cannot be carried down to the attic floor. They are stopped, at the bottom, against a two by three-inch strip *k* which is nailed to the side of the trimmer rafter. At *l* is the ridge board, and *m m m* are the short rafters which form the pitch roof of the dormer. They may be very light, as they are short and carry little weight. They rest, at the foot, on a plate *o*, and at the top bear against the ridge board *l*. In the dormer shown on the right of the figure the rafters *p* are in planes parallel to the main rafters, and a furring piece *s* may be nailed to each of them so as to give the dormer roof any desired curve.

Beside the openings in the roof frame for dormer windows there must be other openings for chimneys and skylights. These are formed in the same way as explained for the dormer openings, with headers and trimmer rafters. A plan of such an opening is shown at *e* in the roof framing plan in Fig. 134.

RAFTER BEVELS.

At the points where the rafters intersect each other the ends must be cut on a bevel so that they will fit against one another accurately. The cutting of these bevels is the most difficult part of the roof framing. There is a different kind of bevel for each of the four kinds of rafters, so they will be considered separately.

Common Rafters. The common rafters are the most simple of all, and the bevels for them are easily cut when the pitch of the roof in which they are to be employed is known. Fig. 149 shows a plan and elevation of one common rafter *c*, with the ridge *a* at one end and the plate *b* at the other. It will be seen that the cuts may be made square across the piece since it is perpendicular to the plate *b* and to the ridge board *a*. There are two cuts to be

The upper edges of the rafters in any roof surface must all lie in the same plane in order that the surface may be smooth and even throughout. It is therefore necessary to work from the upper surfaces of the rafters in laying out the bevels, so that any unevenness which may result from a variation in the depth of the rafters will appear on the under side where it may be corrected by furring. We must start with the point *d*, which is the point in which the line of the upper edge of the rafter intersects the line of the outside face of the wall plate. Then *d e*, which is the distance from the outside face of the wall plate to the face of the ridge board, is the *run* of the rafter, and *e f* is the *rise* of the rafter. The relation between this rise and run is called the *pitch* of the roof surface, and it determines the bevels, which may be easily marked off on the piece with the aid of the steel square.

Fig. 149. Plan and Elevation of Rafter.

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tongue at the point d and with the twelve-inch mark on the blade also on this same edge of the rafter. The line $d s k$ along the tongue of the square is the line of the outside face of the wall plate, and if the rafter is not to project beyond the plate it should be cut on this line. If the rafter is to project beyond the plate so as to form eaves, we must measure off the required distance $k l$ and draw the line $l m$ parallel to $d s k$, cutting the piece on this line.

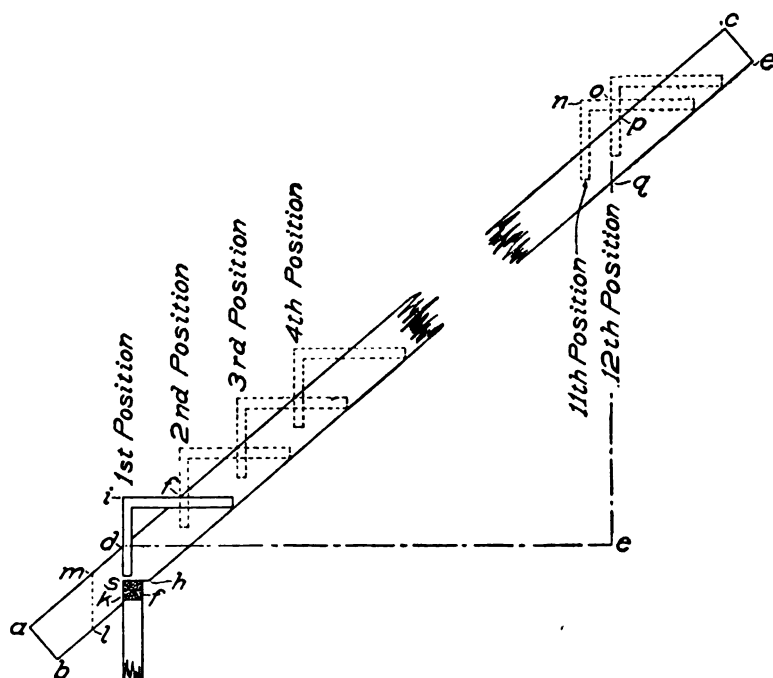


Fig. 150. Cutting Bevel at Top of Rafter.

Now to cut the bevel at the top of the rafter. Let us suppose that the run, the distance $d e$ in Fig. 150, is ten feet and three inches. We will move the square along the edge of the rafter as indicated by the dotted lines eleven times, starting with the first position, shown by the full lines. When the square is in the eleventh position mark off three inches, n to o , on the blade, and slide the square along to the twelfth position. Then the line $p q$ along the tongue of the square will be the line of the face of the ridge board, and the piece should be cut on this line.

A little study of the figure will suffice to reveal to anyone the reason for this method of procedure. Every time the square is moved into a new position it has advanced twelve inches or one foot along the run of the rafter, since the distance $i f$ is twelve inches and is measured horizontally. After the square has been moved ten times it has advanced ten feet along the run of the rafter, and there is then left the three inches of the run which is accordingly measured off as explained above. This gives the position of the top bevel. It should be noticed that for a run of ten feet the square must be *moved along* ten times; for a run of eight feet, eight times; and so on. The run of the rafter may be easily obtained by subtracting one-half the thickness of the ridge board from one-half of the total span of the roof from outside to outside of wall plates. Sometimes the run is taken as exactly one-half the span of the roof, and then the rafter is *cut back* at the top by an amount equal to one-half the thickness of the ridge board. Another way to obtain the exact run of the rafter, from the outside face of the wall plate to the face of the ridge board, is to subtract the total thickness of the ridge board from the total span and divide the result by two.

The rafter must also be cut along the line $s h$ at right angles to the line of the outside face of the plate, so as to rest on the plate, which is shown in the figure as $k s h f$. If it projects beyond the walls of the building to form the eaves, it must be cut on the line $k s$ as well, leaving the notch $k s h$ into which the plate fits. The distance $d s$ may be varied to suit the conditions of each case, but must be made the same for all the rafters in any one roof surface.

The figure shows the rafter in the position which it would occupy in a building, the plate and a part of the wall studding being indicated.

Valley Rafters. We will next consider the valley rafters, and the bevels which must be cut for them. We have seen that in the case of the common rafters the bevels were determined by the pitch of the rafter, and since the same thing holds true for the valley rafters it is first of all necessary to be able to find the pitch of these members. By looking at the rafter c , in the plan in Fig. 134, it will be seen that it is a part of two different roof surfaces,

and that it forms a connecting link between them. Its pitch, however, is different from the pitch of either of these roof surfaces.

To show how this pitch may be found let us consider a special case. Suppose that we have a roof B, with a pitch of twelve inches to the foot which is intersected by another smaller roof A with a pitch of eight inches to the foot, as shown in outline in Fig. 151. In Fig. 152, which is a plan of a part of the same roof, let $a b$ be the ridge of the larger roof and let the dotted line $c d$ be the ridge of the smaller roof. This ridge $c d$ intersects the surface of the larger roof B at some point, as y in Figs. 151 and 152, the location

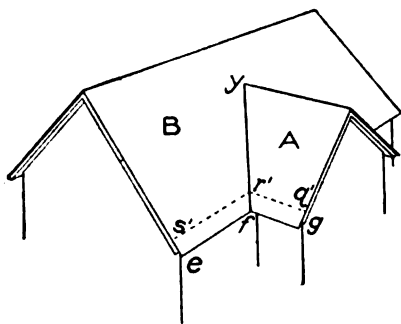


Fig. 151. Intersecting Roofs of Different Pitch.

of which on the plan is as yet unknown. Let the line $a e f g h i$ $j b$ represent the line of the outside face of the plate and let the dotted line just inside of this represent the inside face of the plate. The figure also shows an elevation of a common rafter in each roof and of the valley rafter, with the plate and a portion of the wall studding at k , and the rafters at l . The ridge boards are shown at m . The points g'

f' and e' show where the line of the upper surfaces of the rafters in each roof intersect the line of the outside face of the plate, and these points should all be at the same distance above the top of the plate, so that a line joining them would be horizontal. This may be accomplished when the rafters are cut by making the distance $g' n$ or $e' o$ the same for all of the rafters. It is evident also that the line of each ridge, $c d$ or $a b$, must be horizontal, so that every point in either ridge is at the same level, or at the same distance above the top of the plate, as is every other point in the same ridge line. It may happen, in certain cases, that both ridge lines will be at the same elevation, but usually one ridge will be higher than the other, so that the roofs will intersect as shown in Fig. 151.

We must now find the position and the pitch of the line in which the two roof surfaces A and B intersect. The point f must be one point in this line, and in order to determine the position of

the line we must find one other point in it. All lines in either roof surface which are parallel to the ridge lines, as $q' r'$ and $r' s'$, must be horizontal. Suppose that we draw the line $q' r'$ in the roof surface A, making the distance $g q$ or $g' t$ just one foot. Then since this roof surface A has a pitch of eight inches to the foot, the point q' must be eight inches higher than the points g and f , or the distance $t q'$ must be eight inches. This line $q' r'$ is shown also in Fig. 151. It will be seen that it intersects the roof sur-

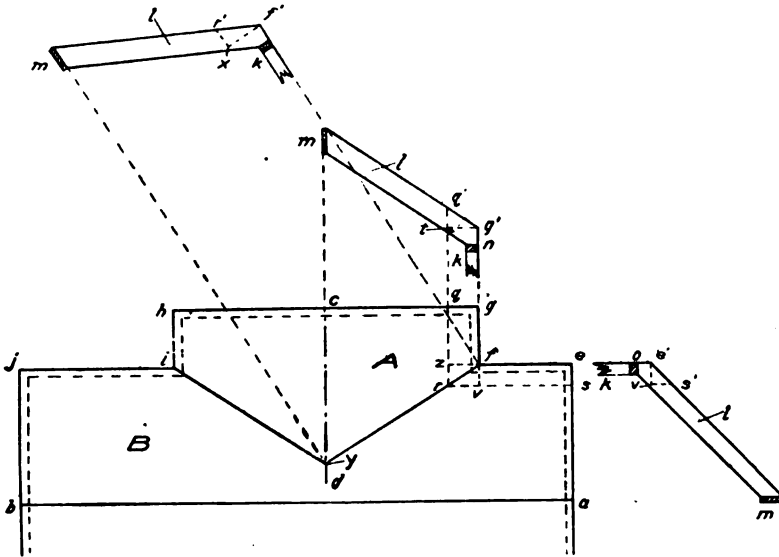


Fig. 152. Plan of Intersecting Roofs.

face B at the point r' and since it is a horizontal line, this point r' must be eight inches above the point e , which is on a level with the points g and f .

Now let us select the point s or s' in the roof surface B and let us suppose that it is also just eight inches above $e f g$. Since the pitch of the roof surface B is not eight inches to the foot like the surface A, but is twelve inches to the foot, the distance $e s$ or $e' v$ will not be twelve inches but will be $\frac{8}{12}$ of 12 inches, or eight inches. If then we draw the line $s' r'$, in the roof surface B, making the distance $e s$ or $e' v$ eight inches, it will be at the same level as the line $q' r'$ in the roof surface A and the point r' must lie in both lines, must be a point in the line of intersection of the

two roof surfaces, and must be eight inches above the point f . The distance $r'x$, then, will be eight inches. A line drawn through the points f and r will give the position of the valley rafter on the plan, and it will be seen that it strikes the ridge cd at the point y . Since fy lies on the roof surface B, the point y must be the point in which the ridge cd cuts the roof surface B, and the valley rafter iy may be drawn at once in plan.

We have found that the distance rz is eight inches and we started with the assumption that the distance fz was twelve inches, so we see that the distance fr or $f'x$ is equal to the square root of the sum of the squares of twelve inches and eight inches which is very nearly fourteen and one-half inches. The distance $r'x$, which is the rise of the valley for the run of fourteen and one-half inches we have found to be eight inches, so we know that the pitch of the valley is eight inches in fourteen and one-half inches, or six and five-eighths inches in twelve inches.

It will be noticed that since the distance fz is twelve inches and the distance rz is, in this case, eight inches, the valley pitches horizontally toward the ridge cy with a pitch of eight inches to the foot. In the same way, since fv is eight inches, and vr is twelve inches, it may be seen that the valley pitches horizontally toward the ridge ab with a pitch of twelve inches in eight inches, or eighteen inches to the foot.

It will be noticed that the distance $f'r'$ on the valley rafter is the length on that rafter which corresponds to a run of fz , or one foot, in the direction of the roof surface A. Also $(f'r')^2$ is equal to $(r'x)^2$ plus $(f'x)^2$. But $f'x$ is the same as fr in the plan so that $(f'x)^2$ is equal to $(fz)^2$ plus $(rz)^2$. Then $(f'r')^2$ must be equal to $(fz)^2$ plus $(rz)^2$ plus $(r'x)^2$. In this particular case, we know that fz is twelve inches, rz eight inches, and $r'x$ eight inches; so that the length on the valley rafter corresponding to a run of one foot toward the ridge cy is equal to the square root of $12^2 + 8^2 + 8^2$. Multiplying this result by the number of feet and fractions of a foot in the half span of the roof A will give us the total length of the valley rafter. The half span of the roof A is shown on the plan as the distance cg ; fz may always be taken as twelve inches, and $r'x$ will always be given by the pitch of the roof surface A, being the rise of this surface per foot of

run. We have only to find, then, the distance $r z$, which is the run of the roof surface B, giving the same rise as occurs in the roof A for a run of one foot. As we have seen $r z$ is easily determined from the pitch of the roof surface B and we can find the length of the valley rafter.

Fig. 153 shows the plan of a roof in which there are a number of different kinds of valley rafters, and the same roof is shown in outline in Fig. 154. There is a main roof A, a small gable B, not so high as the main roof, and a larger gable C, the ridge of which is on the same level with the main ridge. The plan in Fig. 153 shows the method of framing the roof when a small gable intersects the main roof surface. One of the valley rafters $a b$ is car-

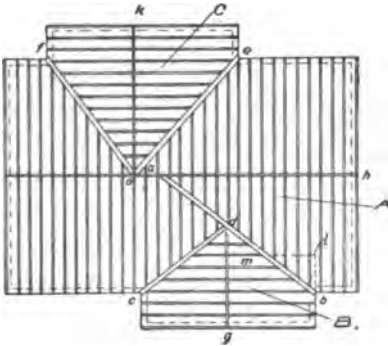


Fig. 153. Plan of Roof with Different Valley Rafters.

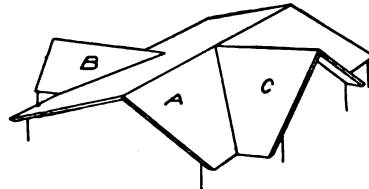


Fig. 154. Outline of Roof with Different Valley Rafters.

ried clear up to the main ridge and bears against it, while the other valley, $c d$, bears against $a b$. It will be seen that the lower part of the rafter $a b$ from b to d lies in both the roof surfaces A and B, but that the portion from d to a lies entirely in the surface A. This plan shows all the different bevels that will have to be cut on valley rafters. At the top of rafter $a b$, where it meets the ridge $i h$, is a single bevel which is determined by the pitch or inclination of the rafter toward this ridge. At the top of the rafter $c d$ is a single bevel which is determined by the angle between $c d$ and $a b$. It will be noticed that this angle is just double the angle between $c d$ and the ridge $d g$, so that it, too, is determined by the inclination of $c d$ toward this ridge. At the top of the rafter $o e$ there are two bevels; one determined by the pitch of the rafter

toward the ridge $o k$, and the other by the pitch of $o c$ toward the ridge $o h$. At the top of the rafter $o f$ are two bevels similar to those at the top of $o c$.

We will now consider how bevels may be cut on the pieces with the aid of the steel square. The cut at the foot of the rafter is simple, and is made in the same way as for a common rafter, as shown in Fig. 150. The distance $d s$ must be the same for every one of the rafters, whether they are valley rafters, common rafters, hip rafters, or jack rafters, and may be varied to suit the circumstances. The notch $k s h$ fits over the plate and the point s is at the upper outside corner of the plate.

We have seen that the length of the valley rafter may be obtained directly from the half span of one of the roof surfaces in which it lies, and this is shown in Fig. 155, which gives in iso-

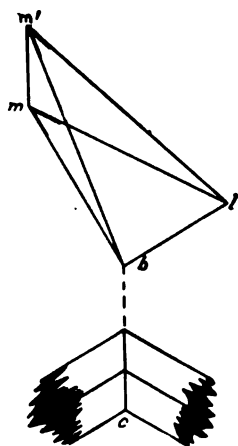
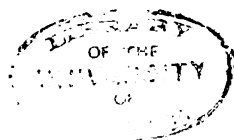


Fig. 155. Calculating Length of Valley Rafters.

metric drawing the lines $b l$, $l m$, and $b m$ in Fig. 153. The distance $b l$ may be taken as just one foot of the half span of the roof A ; the distance $m m'$ is the amount which the roof surface A rises in this run of one foot, and the distance $b m'$ is the actual distance from b to m measured along the line of intersection of the two roof surfaces. The point b corresponds to the point f' in Fig. 152, and a portion of the plate is shown at c .

Referring to the plan in Fig. 153, we see that the line $l m$ is parallel to the ridge $i h$, so that the angle $l m b$ determines the bevel at the top of the rafter $a b$ at a . In Fig. 155, $l m' b$ is the actual bevel and $l m b$ shows the bevel as it appears on the plan. It will be noticed that the angle $l m' b$ is much more acute than the angle $l m b$ on account of the rise of the valley. Note also that the angle $b l m'$ is a right angle, so that the square of $b m'$ is equal to the square of $b l$ plus the square of $l m'$, and that the square of $l m'$ is equal to the square of $l m$ plus the square of $m m'$. Remembering that $b l$ represents just one foot of the span of the roof A , that $m m'$ is the rise of the roof surface A per

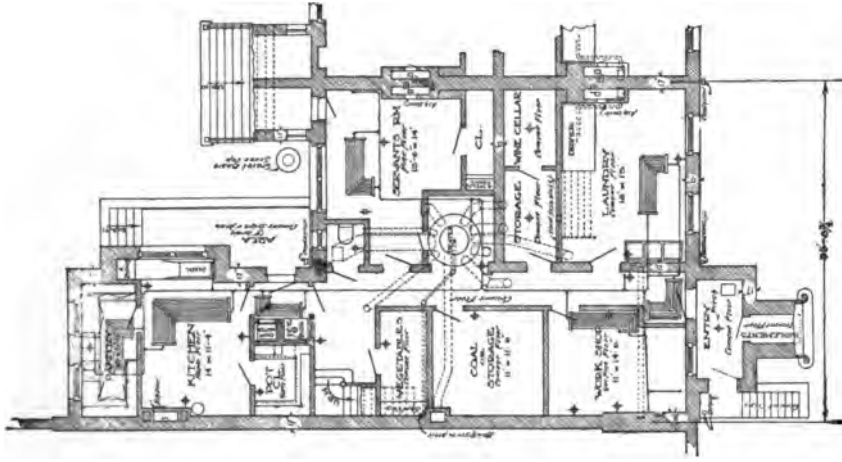
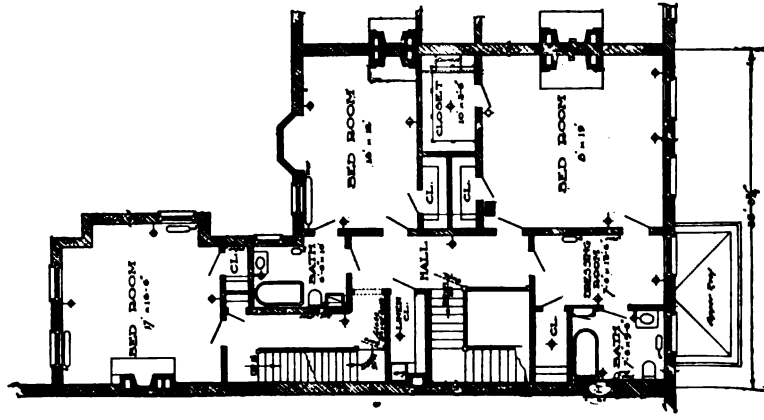
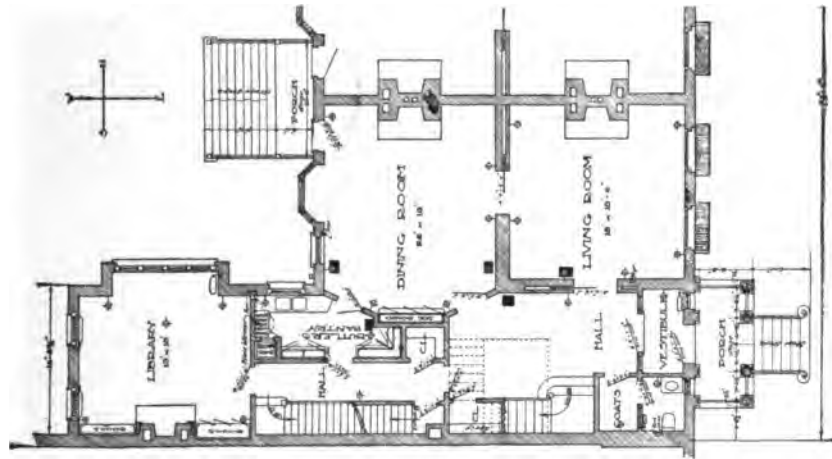




DOUBLE HOUSE BUILT FOR J. J. GLESSNER, ESQ., CHICAGO, ILL.

Shepley, Rutan & Coolidge, Architects, Chicago, Ill.

Walls of Raindrop Brick; Wood Porch with Ionic Columns. For Plans, See Opposite Page.



FIRST, SECOND, AND BASEMENT FLOOR PLANS OF DOUBLE HOUSE FOR J. J. GLESSNER, ESQ., CHICAGO, ILL.

Shepley, Rutan & Coolidge, Architects, Chicago, Ill.

Above Plans are of One House Only, the Other House being Similar. For Exterior, See Opposite Page.



foot of run, and that $l m$ is the run of the roof surface B which will give this same rise, it will be seen that the length $b m'$ may be easily obtained. By using the steel square we may avoid squaring all of these quantities.

In Fig. 156, let us suppose that we have a piece of timber from which we wish to cut the valley rafter. Suppose that we have selected the point m' as the starting point, corresponding to the point f' in Fig. 152, and that we have made the foot cut as shown, and as explained above for the common rafters. We now wish to get the length of the rafter so that we can make the plumb cut or *down bevel* at the top of the piece. If we place the square along the edge of the piece as shown by the light full lines with the distance $m' m$ on the tongue and the distance $l m$ on the blade, we

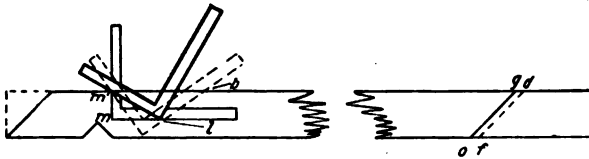


Fig. 156. Framing Valley Rafter.

can at once lay off the distance $l m'$ by marking the points m' and l on the wood.

Now let us place the square in the position shown by the heavier full lines, so that the heel will come at the point l and so that the edge of the tongue will pass through the point m' . We have now the distance $l m'$ laid off along the tongue of the square. Keeping the point m' always in the same position, so that we always have the distance $l m'$ on the tongue of the square, let us revolve the square about the point m' , as shown by the dotted lines, until the twelve-inch mark on the blade coincides with the edge of the rafter at b . We then have the distance $b l$, or one foot, on the blade, $l m'$ on the tongue, and $b m'$ along the edge of the rafter. The distance $b m'$ may be laid off as many times as there are feet and fractions of a foot in the half span of the roof, giving the point d ; then $d f$ is the plumb cut at the top of the rafter parallel to the foot cut, and $g o$ shows where we must cut back to allow for the thickness of the ridge board.

Fig. 157 shows how we may cut the bevel shown at a in the roof plan in Fig. 153. The actual bevel at this point is shown in Fig. 155 by the angle $b m' l$. Let $b m l$ be the center line of the top edge of the rafter. The point l has been found as explained above and corresponds to the point d in Fig. 156. It is the point

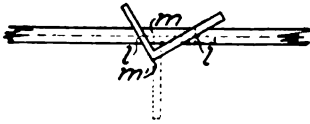


Fig. 157. Cutting Bevel.

in which the center line of the valley intersects the center line of the ridge. First place the square as shown by the dotted lines with the distances on the blade and tongue as shown. A mark may be made at m' which gives the distance $m' l$ and the square may be applied again, with this distance $m' l$ on the blade and $b m'$, equal to just twelve inches, on the tongue. The blade then gives the bevel. The rafter must be cut back, to allow for half the thickness of the ridge.

For the cut at the point d in Fig. 153 where the valley $c d$ comes against the valley $a b$, we apply the square in the same way, as shown in Fig. 158, using different values for the distances $l m$ and $m m'$. The angle $b l m'$ must then be doubled, as shown, and the line $o p$ gives the cut.

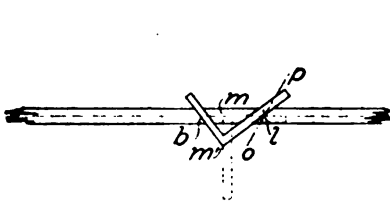


Fig. 158. Cutting Valley Rafters.

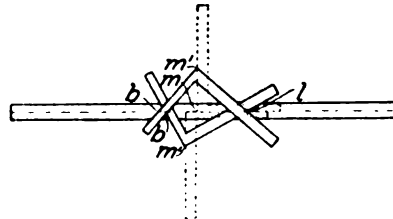


Fig. 159. Cutting Double Bevel.

The double bevel at the point o in Fig. 153 is obtained, as shown in Fig. 159, by applying the square on both sides of the center line of the top edge of the rafter, using different values for $m m'$ and $m l$, according to the pitch of the roof surfaces. This gives the two cuts along the blade of the square, in its two final positions, shown by the full lines.

It will be noticed that in making all of these cuts for valley rafters, there are two distances, $m m'$ and $m l$, which are used as starting points, and by which the position of the square on the piece is determined. $m m'$, as has already been explained, is the

rise of one of the two intersecting roof surfaces, corresponding to a run of one foot, while $m l$ is the run of the other roof surface which corresponds to a rise of $m m'$ in this roof. These distances are easily determined from the pitch of the two intersecting roof surfaces, which is always known, and from them any bevel on any valley rafter can be found, as well as the run, or *scut*, of the valley rafter, its rise, its length, etc.

Hip Rafters. Fig. 160 shows the plan of a roof in which there are some hip rafters. At one end we have a square hip A, and at the opposite end we have a skew hip B. The hip rafters are shown at $a b$, $a c$, $d c$, and $d f$. They rest on the plate at the foot, and bear against the ridge board $a d$ at the top. At $g h$ is shown also a valley rafter. It will be seen that the hip rafter is

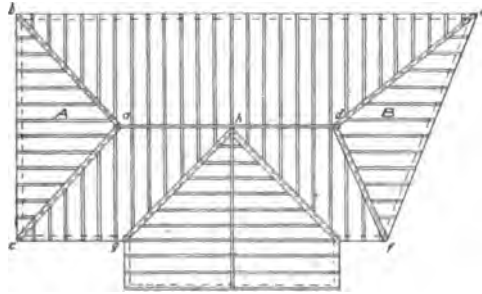


Fig. 160. Plan of Roof with Hip Rafters.

exactly the same as the valley rafter. It has the same pitch, or inclination, toward the ridge $a d$. Its pitch must be the same since it lies in the same roof surface, and is parallel to the valley. This similarity between hip and valley rafters is characteristic, and the same methods of cutting bevels which were explained in connection with valley rafters are equally applicable in the case of hip rafters. The pitch of the hip roofs A and B may be varied to suit the design, but usually the hip roofs have the same pitch as the main roof. The position of the hip rafter on the plan is determined from the pitch of the two roof surfaces of which it is a part in the same way as was explained for valley rafters. All lines in the roof surfaces A and B which are parallel to the plates $b c$ and $e f$ are horizontal, and have the same elevation throughout their length. There is but one bevel at the top of the hip rafter where

it bears against the ridge, and this is similar to that at the top of the valley. It is cut in the same way as the valley rafter.

Curved Hip Rafters. A form of hip rafter which is sometimes a source of considerable trouble is one which occurs in a curved roof, such as an *ogee* roof over a bay window, or a curved tower roof. The shape of the curve to which the top edges of the common rafters must be cut, is determined from the shape of the section of the curved roof surface, but the curve at the top of the hip rafter is entirely different, and must be determined in another way. The principle used in finding this curve is the same as was employed in the case of the valley rafter, namely, that any line drawn in the roof surface parallel to the wall plate must be horizontal, or that it must be at exactly the same elevation throughout its entire length.

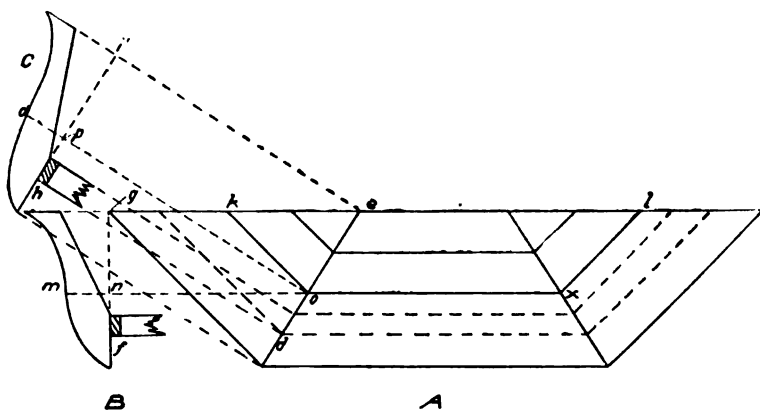


Fig. 161. Ogee Roof over Bay Window.

Fig. 161 shows how this principle may be applied. At A is shown a plan of an ogee roof over a bay window with a hip rafter, *d e* and common rafters. At B is shown an elevation of one of the common rafters cut to coincide with the curve of the roof surface. The shape of the curve may be varied to suit the fancy of the designer. At C is shown an elevation of the hip rafter *d e*, showing the curve to which it must be cut in order to fit into the roof.

To determine this curve we draw on the roof plan at A any number of lines, parallel to the wall plate. These must be horizontal, so that any point in either of the lines is at the same height

above the top of the plate as is every other point in the same line. The lines $f'g$ and hi in the elevation, shown at B and C, represent the level of the top of the plate. By projection we find that the line $k o x l$, for example, is at a distance $m n$ above the top of the plate at the point where it crosses the common rafter shown at B. Every other point in this line is at the same elevation, including the point o , in which it intersects the center line of the hip rafter $d e$. By projection we can locate the point o' in the elevation shown at C, making the distance $o' p$ equal to the distance $m n$.

In the same way we can obtain as many points in the curve of the hip rafter as we have lines drawn on the roof plan. The lines may be drawn as close together as we wish, and the number of points obtained may thus be increased indefinitely. When a sufficient number of points have been thus located, the curve can be drawn through them, and a pattern for the hip rafter is thus obtained. The shape of the curve for a valley rafter is found in the same way as explained for a hip rafter.

Jack Rafters. Fig. 162 shows the plan of a roof in which there are hip, valley, and jack rafters; $a b$ and $b d$ are hip rafters, $c e$ is a valley rafter, and the rest of the framing is made up of common rafters and jack rafters. At $b f$ and $e h$ are shown the ridge boards. Of the jack rafters there are three different kinds; those like $i j$, which run from the valley rafter to the ridge board; those like $k l$, which run from the hip rafter to the plate; and those like $i t$, which run between the hip and valley rafters. These differ from each other only with respect to the bevels which have to be cut on them. The jack rafter $i j$ has a simple plumb cut at the top, where it meets the ridge board, similar to that at the top of a common rafter; and at the bottom i where it meets the valley rafter, it has two cuts—a plumb cut and a cheek cut—which are similar to the cuts on a valley rafter where it comes against a ridge board, as explained above. The

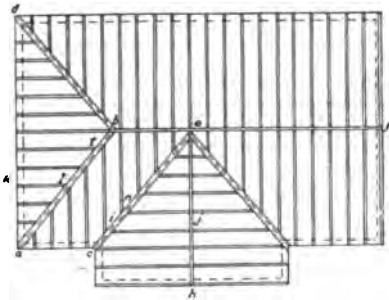


Fig. 162. Roof with Hip, Valley and Jack Rafters.

rafter $k\ l$ has a simple foot cut at the bottom, like that for a common rafter, while at the top it has two cuts like those at the foot of $i\ j$. The rafter $i\ t$ has two cuts at each end, a plumb cut and a cheek cut, where it comes in contact with the hip and valley rafters. All of these bevels can be obtained by the same methods as were employed for finding the bevels on the valley rafters. Everything depends upon the pitch of the roof in which the rafters lie, and the angle between them and the valley or hip rafters. The length of a jack rafter is proportional to its distance from the ridge or plate to which it is parallel, the longest one being equal in length to a common rafter, and the lengths decreasing steadily from this point to the point where the valley meets the ridge, or where the hip meets the plate, as the case may be.

BACKING OF RAFTERS.

Hip Rafters. In Fig. 163 we have a plan, in outline, of a part of a roof with a hip $g\ d$ in which the two surfaces A and B come together. Let us suppose that the pitch of the roof surface

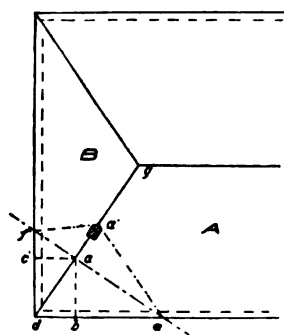


Fig. 163. Part Plan of Hip Roof.

A is eight inches to the foot, and that of the surface B is twelve inches to the foot. Let the lines $f\ c\ d$ and $d\ b\ e$ represent the outside faces of the two wall plates, which come together at the corner, and let the dotted lines just inside of these represent the inside faces of the plates. Suppose that the distance $a\ b$ is just twelve inches, and we have the point a just eight inches above the points b , d and c , since the pitch of the surface A is eight inches to the foot. As the pitch of the surface B is twelve inches to the

foot, the distance $c\ a$ must be eight inches, in order to give a rise of eight inches at the point a , and the distance $d\ b$ must also be eight inches, and $c\ d$ must be the same as $a\ b$, which is twelve inches.

Now suppose that the line $f\ a\ e$ be drawn through the point a perpendicular to the hip line $d\ g$, and let it represent a *vertical* plane which is passed down through the roof surfaces, perpendicular to the plan of the hip line, cutting the hip rafter and plates.

Fig. 164 shows the section of the roof surfaces cut out by this plane. We have the point *a*, eight inches above the points *f* and *e*, making the distance *a h* eight inches. The dotted lines show the roof surfaces, and *a e* and *a f* are the lines which are cut out of these surfaces by the vertical plane. The section *m n o p* shows, much exaggerated in size, the section of the hip rafter cut out by the vertical plane, and it will be noticed that the upper corners of this rafter *a m j* and *a n i* project out into the roof surfaces on each side. These projecting corners must be cut off, so that the section of the rafter will be *a i p o j* and this is called

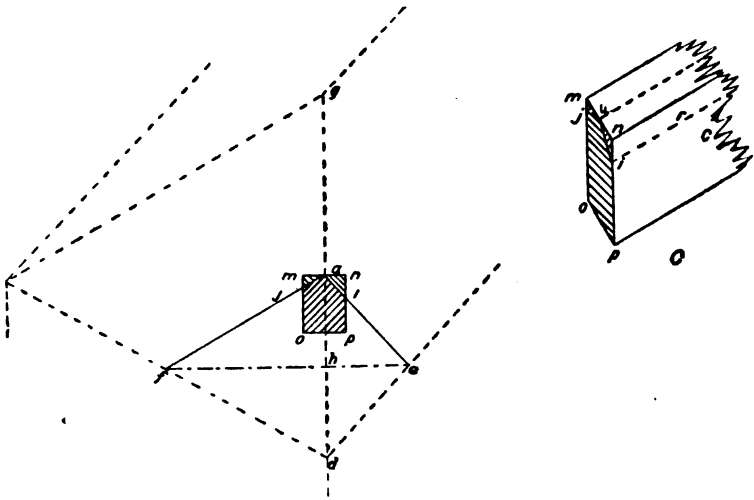


Fig. 164. Section through Roof Surfaces.

backing the rafter. At C is shown an isometric drawing of the rafter, lettered the same as in the section, so that it may be more easily understood just what the *backing* involves.

The question is "How do we know how much to cut off from the corners of the rafter in any particular case, and how can it be indicated on the piece of timber so that these cuts can be made?" This question will now be answered.

In making the foot cut on the rafter, we have to cut out just such a vertical section as is indicated in Fig. 164. We can find the point *a* on this section in the center of the top edge of the rafter and draw lines *a j* and *a i* directly on the section of the piece, and from the points *i* and *j* lines like *i r*, in the isometric

view at c' , can be drawn on the sides of the rafter, which will show the amount to be cut off from the corners. In order to do this, however, we must know the bevel of the lines $a e$ and $a f$; that is, we must know the angles $n a i$ and $m a j$ for any particular case. In the case we are considering we know that the distance $a h$, Fig. 164, is eight inches, as explained above, and we need only to find the distances $h e$ and $h f$ in order to determine the two bevels. The distances $a e$ and $a f$ in the plan, Fig. 163, are the same as $h e$ and $h f$ in Fig. 164. Now let us find $a e$. The length of $a b$ was assumed at the start to be twelve inches, and $d b$ was found to be eight inches. On account of the similarity of triangles, $\frac{d b}{a b}$ is equal to $\frac{a b}{b e}$, so that $b e$ is $\frac{12}{8}$ of $a b$, or eighteen inches. Then $a e$ must be about twenty-one and one-half inches, and $h e$ in Fig. 164, is the same. We now know both $h e$ and $a h$ in Fig. 164, and these two distances determine the bevel of the line $a e$. In the same way, the distance $h f$ may be found and the bevel of the line $a f$ may be determined. It may sometimes be found more convenient to draw the roof plan accurately to scale and then to scale the distances, instead of calculating them, but this

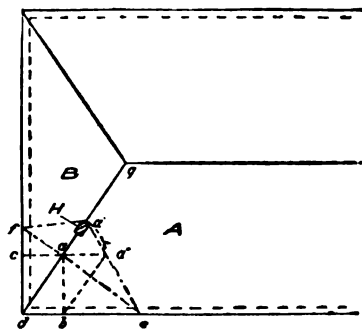


Fig. 165. Graphical Method of Finding Bevels.

amounts to the same thing in the end. The bevels of the lines $a f$ and $a e$ may also be found graphically as shown in Fig. 165. Suppose this plan to be drawn accurately to a fairly large scale. Starting with the point a on the hip line $d g$, we draw the line $e a f$, perpendicular to the hip line, and the lines $a b$ and $a c$ perpendicular to the wall lines $d e$ and $d f$. From b we can draw the line $b a''$ making the same

angle with $a b$ that the roof surface A makes with the horizontal plane. Then if $a a''$ be drawn from a perpendicular to $a b$ the distance $a a''$ will be equal to the actual elevation of the point a above the point b . Thus distance can be laid off along the hip line, $d g$ perpendicular to the line $f a e$, by swinging the point a'' around

to a' . Then the distance $a a'$ is equal to the elevation of the point a above the point b , and above the points e and f also. The lines $a' e$ and $a' f$ make the same angle with the line $f a e$ that the lines $a e$ and $a f$, in Fig. 164, make with the horizontal, and we can get the bevels from these lines. At II is shown a small section taken vertically through the hip rafter, similar to the section of the rafter shown in Fig. 164.

Valley Rafters. In Fig. 166 we have a plan in outline of a part of a roof with a valley $a b$ between the roof surfaces C and D and with ridges $h c$ and $b d$. Let us assume the pitches of the roof surfaces to be, as before, eight inches to the foot for C and twelve inches to the foot for D. Assume $a e$ to be twelve inches, and $e f$ will be eight inches and the point f must be eight inches

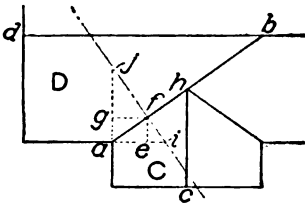


Fig. 166. Roof with Valley and Ridges.

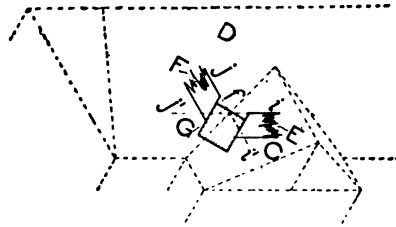


Fig. 167. Method of Finding Bevels.

above the point a , as explained in the case of the hip rafter. Since we know $a e$ and $e f$ in Fig. 166 we can find $e i$ from the similarity of the triangles, as in the case of the hip rafter, and then we can find both $a i$ and $f i$. Knowing $a i$, and knowing the pitch of the roof surface C, we can find the elevation of the point i above the point a . Since we know that the point f is eight inches above the point a we can find the elevation of the point i above the point f , and this with the distance $f i$ will give the bevel of the line $f i$ in Fig. 167. In the same way the bevel of the line $f j$ may be found. These bevels can be laid off on the vertical section of the valley rafter which is cut out when the foot cut is made, and the distances at which the tops of the jacks, E and F in Fig. 167, must be set above the top of the valley rafter g may be determined. In order that the lines $f i$ and $f j$ in Fig. 167 may come on the surface of the valley rafter section, they may be drawn

sloping downward instead of upward, as shown at $f'i'$ and $f'j'$. The point f is always in the center of the top edge of the valley rafter.

Fig. 168 shows how the bevels for the valley rafter may be found graphically. Starting with the point f we can draw lines

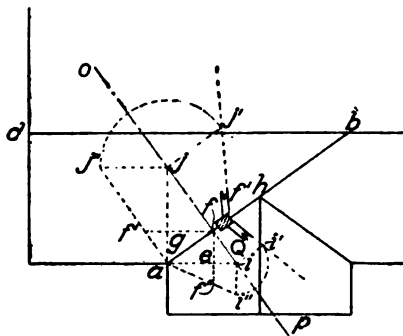


Fig. 168. Graphical Method of Finding Bevels.

$o-f-p$, $a-e-i$, and $a-g-j$ perpendicular respectively to the valley line $a-h$ and to the two outside wall lines. The lines $a-i''$ and $a-j''$ having been drawn corresponding to the pitches of the two roof surfaces, we have the distances $i-i''$ and $j-j''$ showing the elevation of the points i and j . These distances can now be swung around perpendicular to the line $o-f-p$, so as to give

the points i' and j' . The distances $e-f'''$ and $g-f'''$, which should be the same, show the elevation of the point f , and this distance may be laid off perpendicular to $o-f-p$, as shown at $f-f'$. Then the lines $f'i'$ and $f'j'$ correspond to the lines $f-i$ and $f-j$, in Fig. 167, and give the bevels which we need. At Q is shown a vertical section of the valley rafter and the jack rafters similar to Fig. 167.

ATTIC PARTITIONS.

It is often necessary to build partitions in the story directly beneath the roof, and such partitions must extend clear up to the under side of the rafters and connect with them in some way. This makes it necessary to cut the tops of the studs on a bevel to correspond with the pitch of the rafters, and the cutting of this bevel is not always an easy task. Fig. 169 shows the framing plan of the roof of a small simple building. $a-b$ is the ridge. The plate extends around the outside from c to d to e to f , and back again to c ; and $g-h$, $i-j$, $k-l$ are the rafters. A partition is shown beneath the roof running diagonally across the building, making an angle with the direction of the rafters and an angle with the direction of the ridge. At $n-o$ is shown another partition running parallel to the ridge, and at $p-q$ still another, running

parallel to the rafters. Now since all the rafters slope upwards from the plate to the ridge, it is evident that the tops of all the studs must be cut on a bevel if they are to fit closely against the undersides of the rafters. This is illustrated in Fig. 170, where the stud A must fit against the rafter B.

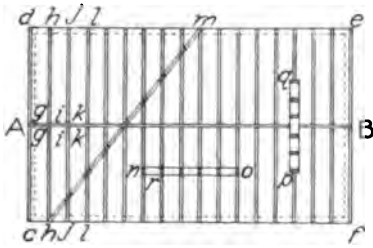


Fig. 169. Framing Plan of Small Roof.

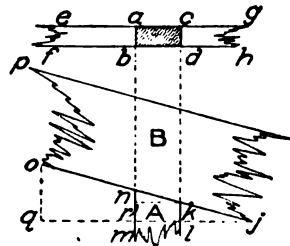


Fig. 170. Connection of Studs and Rafters.

To take the simplest case first, let us consider the stud marked *r*. Since all the rafters have the same pitch or slope, all the studs in the partition *n o* will have the same bevel at the top, and if we find the bevel for one we can cut the bevel for all. Fig. 170 shows this stud drawn to a larger scale and separated from the rest; *a b c d* is a plan of the stud, and the rafter is shown at *e f g h*. We will take the distance *f h*, or the run of the part of the rafter shown, as one foot exactly. Now if *A* and *B* represent a side elevation of the rafter and stud looking in the direction shown by the arrow, the *run* of the part of the rafter shown is the distance *j q*, and the distance *q o* should be equal to the *rise* of the rafter in one foot. Let the rise in this case be nine inches. Then *k n* shows the bevel of the top of the stud. If the stud is a two by four stick, the distance *k r* is just four inches, or one-third of the run of the rafter, and consequently the distance *r n* is just three inches, or one-third of the rise of the rafter.

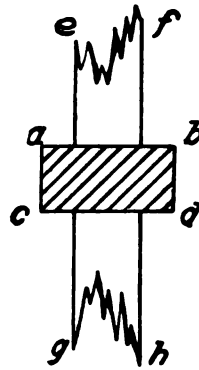


Fig. 171. Stud and Rafter.

In the case of the studs forming the partition *p q* in Fig. 169, the bevel is found in the same way, the only difference being that the rafter now crosses the stud, as shown in Fig. 171, where

$a b c d$ is the stud and $e f g h$ is the rafter, both shown in plan.

In the case of the partition $h m$, Fig. 169, we have to deal with a somewhat more difficult problem because the rafter crosses the studs diagonally and the studs must be beveled diagonally on top so that the bevel will run from corner to corner instead of straight across the stud from side to side. An enlarged plan of one stud with the rafter running across it is shown in Fig. 172.

Let $a b c d$ be the stud and $e f g h$ the rafter; $i j k l$ shows the rafter in elevation looking in the direction shown by the arrow, and $a' b' c' d'$ shows the stud as seen from this same direction. The corner d of the stud cannot be seen from this side and is shown as a dotted line in the figure. The rafter cuts across the corners of the stud at the points $a' b' c'$ and d' , giving the bevel shown in the figure. This bevel may be cut by

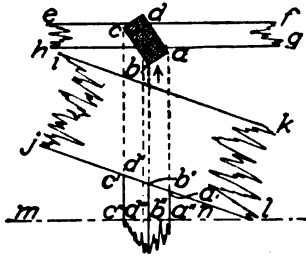


Fig. 172. Stud and Diagonal Rafter.

drawing any line all the way around the stud, square with the edges, as shown at $m n$, and laying off from this line on the edges of the stud the distances $a' a''$, $b' b''$, $c' c''$, and $d' d''$. Lines drawn across the faces of the stud connecting the points so obtained will give the exact bevel.

SPECIAL FRAMING.

We have, in the preceding pages, considered the framing which enters into a building of light construction, such as an ordinary dwelling house, but there are certain classes of structures which call for heavier framing, or framing of special character. Among these may be mentioned *battered* frames, or frames with inclined walls; *trussed* partitions; *inclined* and *bowled* floors; special forms of reinforced beams and girders; the framing for balconies and galleries; timber trusses; towers and spires; domes, pendentives and niches; and vaults and groins. These subjects will be now taken up and discussed, and the methods employed in framing such structures will be explained.

Battered Frames. Sometimes it is necessary to build a structure with the walls inclined inward, so that they approach

each other at the top, and so that the top is smaller than the bottom. This is the case with the frames which support water tanks or windmills. An elevation of one side of a frame of this kind is shown in Fig. 173 with a plan in outline at A. It will be seen that the corner posts *a a* are inclined and approach each other at the top, so that they are not perpendicular to the sill at the bottom. This means that the foot of the post, where it is tenoned into the sill, must be cut on a bevel, and the bevel must be cut diagonally across the post, from corner to corner, since the post pitches diagonally toward the center, and is set so that its outside faces coincide approximately with the planes of the sides of the structure as indicated in the plan shown in Fig. 174. The girts *b*, Fig. 173, will also have to have special bevels cut at their ends, where they are framed into the posts.

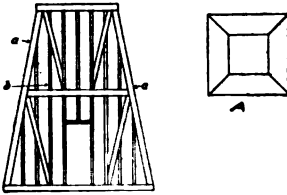


Fig. 173. Battered Frame.

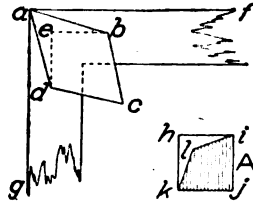


Fig. 174. Bevel of Corner Post.

After a corner post has been cut to the proper bevel to fit against the sill the section cut out at the foot will be diamond-shaped, as shown at *a b c d* in Fig. 174, which shows a plan of one corner of the sill. It will be noticed that the faces *a b* and *a d* of the post do not coincide with the edges of the sill *a f* and *a g*. If the structure is merely a frame and is not to be covered over with the boarding on the outside, it is not necessary that the outside faces of the post should coincide exactly with the planes of the sides of the structure, and in this case posts of square or rectangular section may be used, with no framing except the bevels and the mortises for the girts. If, however, the frame is to be covered in, the post must be *backed* so as to be able to receive the boarding.

The backing consists in cutting the post to such a shape that when the bevel is cut at the foot, the section cut out will be similar to that shown at *e b c d* in Fig. 174. The *backed* post must then

be set on the sills so that the point *c* will come at the corner *a*. The face of the post *c b* will then coincide with the face of the sill *a f*. The post should be backed before the bevels are cut because setting it back the distance *a c* may make a difference in the required length between bevels. If the post was of square section before backing it will have, after backing, a peculiar rhombus-shaped section, as is shown at A in Fig. 174. Here *h i j k* shows the original square section, and *l i j k* shows the section after backing. These sections are taken square across the post perpendicular to the edges.

Fig. 175 shows how the amount of backing necessary in any particular case may be determined. Suppose that we have a case where the frame is not square in plan, as shown in Fig. 173, but

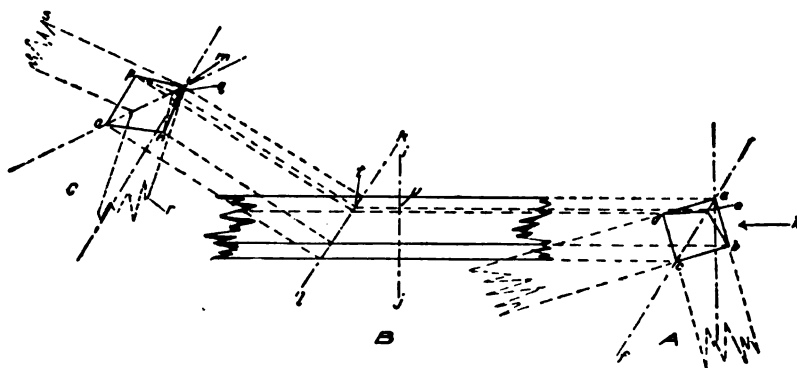


Fig. 175. Determining Amount of Backing.

is rectangular, one side being much longer than the other. In this case the diagonal of the frame formed by the sills will not coincide with the diagonal of the section of the post. Fig. 175 shows at A a plan of the post as it would appear if it were set up perpendicular to the sills. The sills are shown by the dotted lines. At B is shown an elevation of the post looking in the direction shown by the arrow *h*. The section shown at A is taken on the line *i j*. In the frame, however, the post is inclined toward the center, so that the section cut out at the foot of the post by the plane of the top of the sill will not be square with the edges of the post as is the section *i j*, but will be at an angle with them. Such a section is taken on the line *k l* and is shown at C.

The section of the post is shown by $m n o p$ and the sill is indicated by the dotted lines. The post must now be backed so that this section will take the form shown by $q n o p$, the sides $p q$ and $n q$ being parallel to the sides of the sill $m r$ and $m s$. This point q determines the position of the outside corner of the post after it has been backed and corresponds to the point t on the line $k l$. Then the line $t u$ is the elevation of the outside corner of the post after backing, and the section $i j$ cuts this line at u . The corner shown by the line $t u$ must be diagonally opposite the inside corner of the post, so it must be indicated on the section shown at A by the point e . Then $e b c d$ is the shape to which the post must be trimmed. This can be laid out on the square end of the rough post and it can then be trimmed to the correct shape. The backing will then be complete.

Fig. 176 shows how the foot cut for the inclined post may be obtained by using the steel square. In Fig. 173 it will be seen that the post a slopes toward the center in the elevation there shown, and it likewise slopes toward the center in the other elevations, either with the same pitch or with a different pitch. The result of the two slopes is to cause the post to slope diagonally. It is an easy matter to find the pitch in each elevation since it depends upon the size of the base and top, and the height between them. We then have the two pitches, the combination of which gives the true pitch, diagonally. They can, however, be treated separately. The square may be applied to the post, as shown in Fig. 176, with the rise on the blade and the run on the tongue, and a line may be drawn along the tongue. The post can then be turned over and the pitch shown in the other elevation may be laid off on the adjacent side in the same way with the rise on the blade and the run on the tongue of the square. Thus a continuous line $a b c d$ may be drawn around the post and it can be cut to this line.

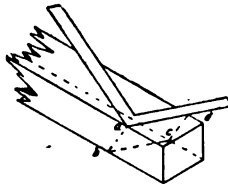


Fig. 176. Marking Foot Cut.

Trussed Partitions. It is very often necessary to construct a partition in some story of a building above the first, and in such a position that there can be no support—as, for instance, a partition in the story below—beneath it. In this case the partition

must be made self supporting in some way. The usual method is to build what is known as a trussed partition. This consists of a timber truss, light or heavy, according as the distance to be spanned is small or great, which is built into the partition and covered over with lathing and plastering or with sheathing.

Fig. 177 and 178 show two forms of trussed partitions which are in common use. The one shown in Fig. 177 may be employed for a solid partition, or a partition with a door opening in the middle, while the one shown in Fig. 178 is applicable where the wall must be pierced by door openings in the sides. The truss must be so designed that it will occupy as little space as possible in a lateral direction, so that the partition need not be abnormally

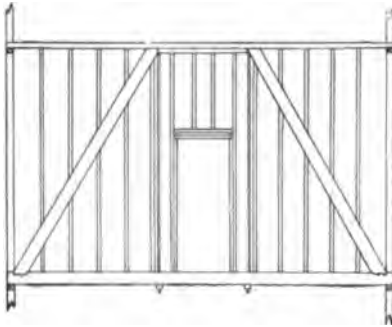


Fig. 177. Trussed Partition.

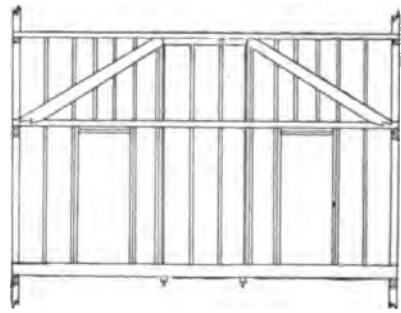


Fig. 178. Trussed Partition.

thick. If possible it is best to make the truss so that it will go into a four-inch partition, but if necessary five or six-inch studding may be used and the truss members may be increased in size accordingly. The faces of the truss members should be flush with the faces of the partition studding, so as to receive lathing or sheathing.

The size of the truss members depends entirely upon the weight which the partition is called upon to carry. Besides its own weight a partition is often called upon to carry one end of a set of floor joists, and sometimes it supports columns which receive the whole weight of a story above. In any case the pieces must be very strongly framed or spiked together, and sound material, free from shakes and knot holes, must be used.

Inclined and Bowled Floors. In any large room which is to be used as a lecture hall, the floor should not be perfectly level

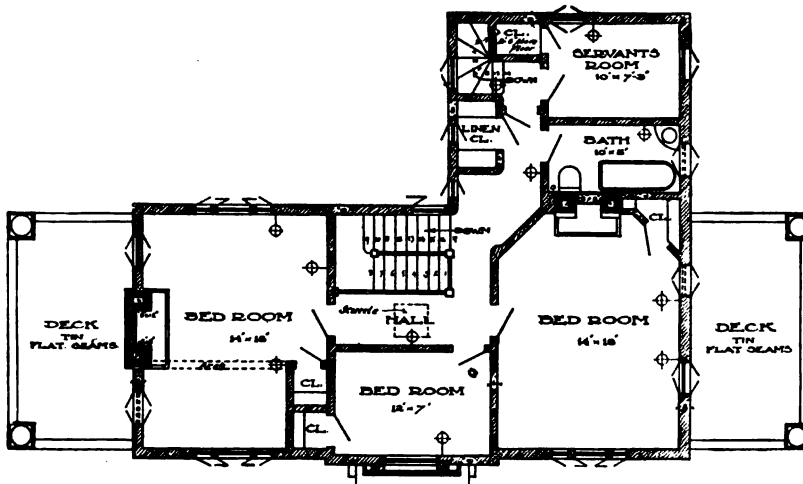
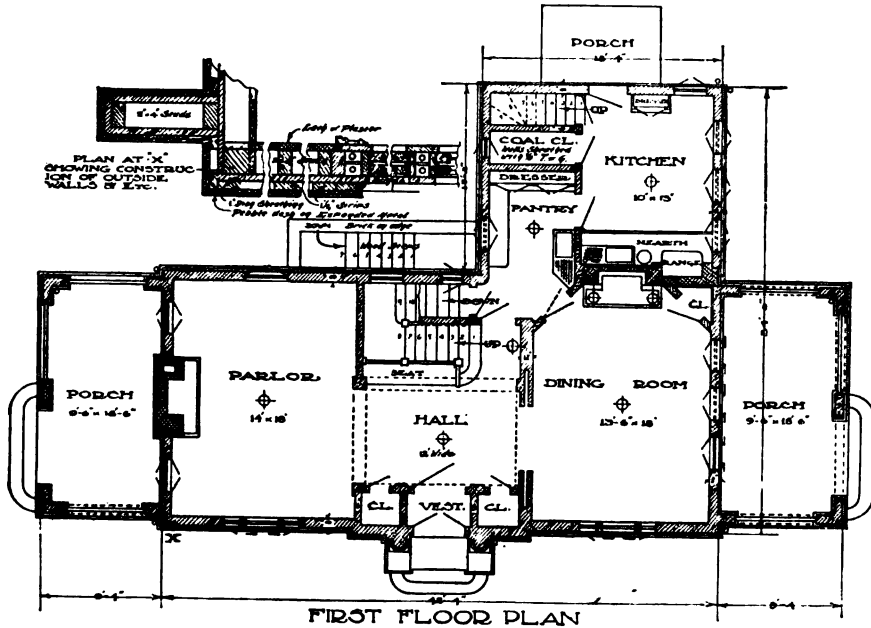




RESIDENCE OF MRS. BACHRACH, WASHINGTON, D. C.

Wood, Donn & Deming, Architects, Washington, D. C.

Walls of Stucco on Wire Lath. A Three-Quarter Engaged Ionic Column Used on Entrance Feature. For Plans, See Opposite Page.



PLANS OF RESIDENCE OF MRS. BACHRACH, WASHINGTON, D. C.
Wood, Donn & Deming, Architects, Washington, D. C.



throughout, but should be so constructed as to be higher at the back of the room than it is at the front. The fall of such a floor from back to front should be not more than three quarters of an inch in one foot, and a fall of one-half an inch in one foot is much better. If the floor has a greater slope than this it becomes very noticeable when anyone attempts to walk over it.

The simplest way to arrange for the slope is to construct what is known as an *inclined* floor, which rises steadily from front to

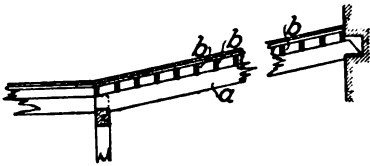


Fig. 179. Inclined Floor.

back so that a line drawn across it from side to side, parallel to the front or rear wall of the room, will be level from end to end. There are two methods of building an inclined floor, the difference between them being in the arrangement of the girders and

floor joists. The two methods are shown in Figs. 179 and 180.

Fig. 179 shows the arrangement when it is necessary to have the girders run from the back to the front of the room, parallel to the slope of the floor. In this case the girders *a* are set up on an incline, and the joists *b* resting on top of them, are level from end to end. Each line of joists is at a different elevation from the lines of joists on each side of it. The floor laid on top of the joists will then have the required inclination. The slope of the girders must be the same as the slope required for the finished floor.

Fig. 180 shows the arrangement when it is desired that the girders shall run from side to side of the room, at right angles to the direction of the slope of the floor. The joists *a* will then be

parallel to the direction of the slope, and are inclined to the horizontal, while the girders *b* are level from end to end. Each line of girders is at a different elevation from every other line of girders, and these elevations must be so adjusted that the joists

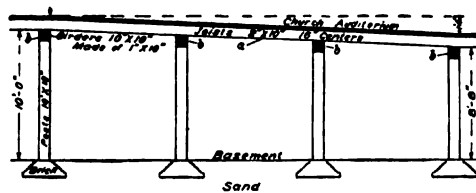


Fig. 180. Inclined Floor.

resting on top of the girders will slope steadily from end to end.

When a simple inclined floor is employed, the seats must be arranged in straight rows, extending across the room from side to side, so that each line of seats may be level from end to end. This arrangement is not always desirable, however, and it is often much better to have the seats arranged in concentric rings all facing the speaker's platform. In this case a *bowled* floor must be built. A bowled floor is so constructed that a segment of a circle, drawn on the floor from a center in the front of the room, on, or near, the speaker's platform, will be perfectly level throughout its

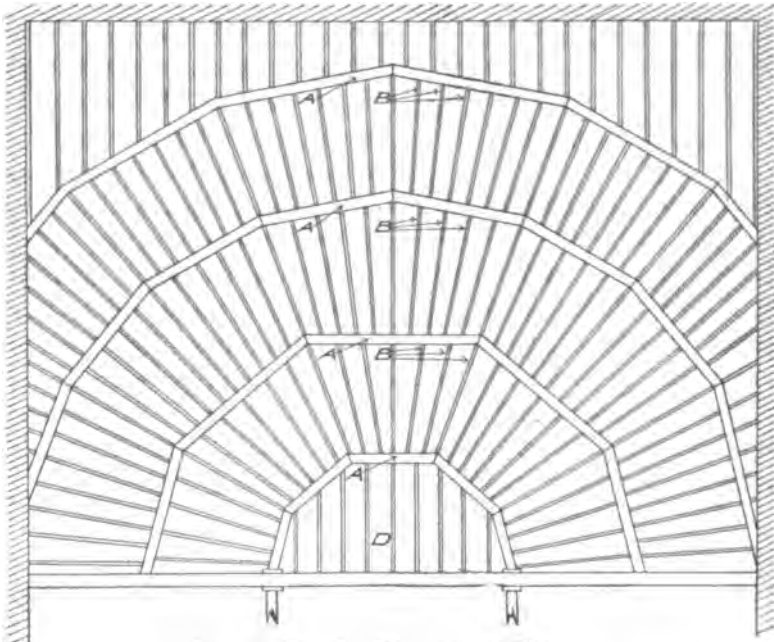


Fig. 181. Framing Plan of Bowled Floor.

length. This means that the floor must pitch upward in all directions from the speaker's platform or, in other words, it must be *bowled*. There are two methods of constructing a floor of this kind. The simplest way is to build first an ordinary inclined floor, which slopes from the front to the back of the room, and then to build up the bowled floor with furring pieces. This method should always be followed when it is necessary to keep the space beneath the lecture hall free from posts or columns.

The second method is to arrange girders, as shown in the framing plan of a bowled floor in Fig. 181. These girders A A are tangent to concentric circles which have their center at the speaker's platform, and each line of girders is at a different elevation. The elevations of the different lines of girders are so adjusted that the floor joists B B which rest on them will slope steadily upward as they recede from the platform. The girders may be supported on posts beneath the floor of the hall, and if the space under the floor is not to be used for another room, this is a very good method to employ.

Immediately around the platform there will be a space D, the floor of which will be level, and the slope will start several feet away from the platform.

Heavy Beams and Girders. For ordinary frame buildings, there will be no difficulty in obtaining timbers large enough for every purpose, but in large structures, or in any building where heavy loads must be carried, it is often impossible to get a single stick which is strong enough to do the work. In this case it becomes necessary to use either a steel beam or a trussed girder of wood, or to build up a compound wooden girder out of a number of single sticks, fastened together in such a way that they will act like a single piece.

Steel beams are very often employed for girders when a single timber will not suffice, and although they are expensive, the saving in labor helps to offset the extra cost of the material.

Wherever wooden joists or girders come in contact with a steel beam they must be cut to fit against it. The steel shape most commonly employed is the I-beam, and the wooden members must be cut at the ends so as to fit between its flanges. This is shown in Fig. 182. The joist *b* is supported on the lower flange of the I-beam *c* and the strap *a* prevents it from falling away from the steel member. The strap is bolted or spiked to the wooden beam and is bent over the top flange of the steel beam as shown. If two wooden beams frame into the steel beam opposite each other, a straight strap may be used, passing over the top of the steel beam and fastened to both the wooden beams, thus holding them together. If a better support is desired for the end of the wooden beam, an angle may be riveted to the web of the steel I-beam, as

shown in Fig. 183, and the end of the wooden joist may be supported on the angle. This is an expensive detail, however, and it is seldom necessary.

If a timber is not strong enough to carry its load, and if it is not desirable to replace it with a steel beam, it may be strengthened by trussing. There are two methods of trussing beams; by the

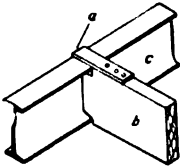


Fig. 182. I-Beam and Wooden Joist.



Fig. 183. I-Beam Construction.

addition of compression members above the beam, and by the addition of tension members below it. The first method should be employed whenever, for any reason, it is required that there be no projection below the bottom of the beam itself. The second method is the one most commonly used, especially in warehouses, stables, and other buildings where the appearance is not an important consideration.

In Fig. 184 is shown a beam which is trussed by the first method, with compression pieces *a a a* above the beam. All the parts are of timber excepting the rods *b b* which may be of wrought iron or steel. The beam itself is best made in two parts *e e* placed

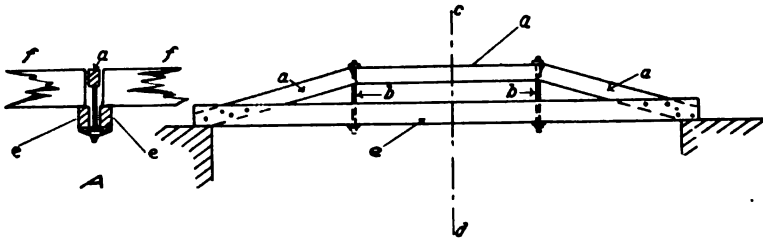


Fig. 184. Trussed Beam.

side by side, as shown in the section at A, with the parts *a a* fitting in between them. The section shown at A is taken on the line *c d*. The depth of the girder may be varied to suit the conditions of each case. In general the deeper it is made the stronger it becomes, provided that the joists are made sufficiently strong.

Usually girders of this kind are made shallow enough so that they will be contained in the thickness of the floor and will not project above it. A slight projection below the ceiling is not a serious disadvantage. The floor joists *ff* may be supported on the pieces *ee*, as shown at A.

In Figs. 185 and 186 are shown examples of girders which are trussed by the second method, with tension rods *dd* below the

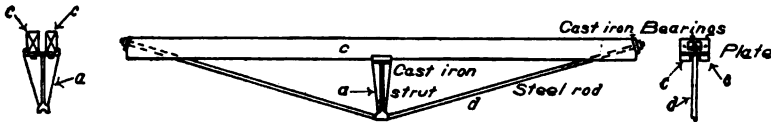


Fig. 185. King Post Trussed Beam.

beam. These rods are of wrought iron or steel, and the struts *aa* are of cast iron. The struts may be made of wood if they are short, or if the loads to be carried are not heavy. Sometimes the girders are made very shallow, and the struts *aa* are then merely wooden blocks placed between the beam *c* and the rod *d* to keep them apart. The girder shown in Fig. 185 is known as a *king-post* trussed beam, while the one shown in Fig. 186, with two struts instead of one, is known as a *queen-post* trussed beam. The beam itself *c* may be made in two pieces side by side with the rods and the struts fitting in between them, or it may be a single

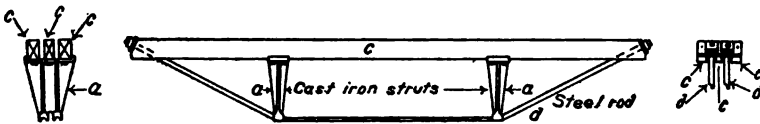


Fig. 186. Queen Post Trussed Beam.

stick, and the rods may be made in pairs, passing one on each side of the beam. In the latter case the struts would simply bear against the bottom of the beam, as shown in the illustrations, being fastened to it by bolts or spikes, so that they will not slip sideways.

It sometimes happens that a heavy girder is required in a situation where trussing cannot be resorted to, and where steel beams cannot readily be obtained. In this case the only resource is to build up a compound beam from two or more single pieces. A girder of this kind can be constructed without much difficulty, and can be so put together as to be able to carry from eighty to

ninety per cent of the load which a solid piece of the same dimensions will bear. There are many ways of combining the single timbers to form compound beams, some of the most common of which will be described.

The most simple combination is that shown in Fig. 187. The two single timbers are bolted together side by side, with sometimes a small space between them. The bolts should be spaced about two feet apart and *staggered*, as shown, so that two will not come side by side. Usually bolts three-quarters of an inch in diameter are used.

In Fig. 188 is shown a modification of this girder known as a *flitch-plate girder*. It has a plate of wrought iron or steel, inserted between the two timbers, and the whole is held firmly together by bolts. The size of the plate should be in proportion to the size of the timbers, so as to make the most economical combination.

If we have two pieces of timber out of which we wish to make a compound girder, it is almost always possible to get a stronger combination by placing them one on top of the other, than by placing them side by side. This is because the strength of a beam varies as the *square of its depth*, but only *directly as its width*. For this reason most compound girders are composed of single sticks placed one above the other. The tendency is for each piece to bend independently, and for the two parts to slide by each other, as shown in Fig. 189. This tendency must be overcome and the parts so fastened together that they will act like a single piece. There are several methods in common use by which this object is accomplished.

Fig. 190 shows the most common method of building up a compound girder. The timbers are placed together, as shown, and narrow strips of wood are nailed firmly to both parts. The strips are placed close against each other and have a slope of about forty-five degrees, sloping in opposite directions, however, on opposite sides of the girder. It has been claimed that a built up girder of this kind has a strength ninety-five per cent as great as the strength of a solid piece of the same size, but it is very doubtful whether this is true in most cases. Actual tests seem to indicate that such girders have an efficiency of only about seventy-five

per cent. They usually fail by the splitting of the side strips, or the pulling out and bending of the nails, but seldom by the breaking of the main pieces. It is, therefore, essential that the strips should be very securely nailed to each of the parts which make up the girder, and that they should also be carefully selected so that only those pieces which are free from all defects may be used.



Fig. 187. Compound Beams.

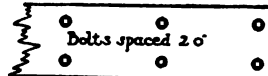
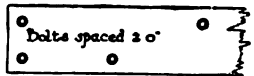


Fig. 188. Flitch-Plate Girders.



These girders are liable to considerable deflection, and should not be used in situations where such deflections would be harmful.

In Fig. 191 is shown another form of girder with the parts notched, as shown, so as to lock together. This prevents them from slipping by each other. Bolts are employed to hold the parts

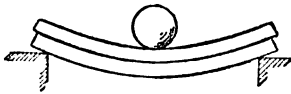


Fig. 189. Flexure of Compound Beams.



Fig. 190. Compound Girder.

together, so that the surfaces will always be in close contact. While this form of girder is very easily constructed, it has many disadvantages. A great deal of timber is wasted in cutting out the notches, as these must be deep enough to prevent crushing of the wood at the bearing surfaces, and thus the full strength of the sticks is not utilized. Moreover, it is apt to deflect a good deal,

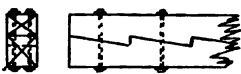


Fig. 191. Notched Beam.



Fig. 192. Keyed Beam,

and its efficiency is not so great as that of other forms. On the whole it is considered to be greatly inferior to the form of girder previously described.

The form of compound beam which is almost universally considered the best is that shown in Fig. 192. This is known as the

keyed beam, its characteristic feature being the use of *keys* to keep the parts from sliding on each other. The strength of a keyed beam has been found by actual experiment to be nearly ninety-five per cent of the strength of the solid timber, while the deflection when oak keys were used was only about one-quarter more than the deflection of the solid beam. By using keys of cast iron instead of wood this excess of deflection in the built-up girder can be reduced to a very small percentage. The keys should be made in two parts, each shaped like a wedge, as explained in connection with the keys for tension splices, and should be driven from opposite sides into the holes made to receive them, so as to fit tightly. They should be spaced from eight to sixteen inches apart, center to center, according to the size of the timbers, and should be spaced more closely near the ends of the beam than near the middle. In the center of the span there should be left a space of four or five feet without any keys.

Balconies and Galleries. In churches and lecture halls it is almost always customary to have one or more balconies or galleries, extending sometimes around three sides of the main auditorium, but more often in the rear of the room only. These galleries are supported by the wall at the back and by posts or columns in front, and the framing for them is usually a simple matter.

Fig. 193 shows a sectional view of a gallery frame, as they are commonly constructed. There is a girder *a* in front, which rests on top of the columns *c*, and supports the lower ends of the joists *b*, forming the gallery floor. The size of these pieces will depend upon the dimensions of the gallery, the spacing of the columns which support the girders in front, and various other considerations. Usually joists two by ten or three by twelve, and girders eight by ten or ten by twelve will be found to be sufficiently strong. The joists should be spaced from fourteen to twenty inches, center to center. Very often cast iron columns are employed to support the girders. At the top, where the joists rest on the wall, they should be cut, as shown in the figure, so that they may have a horizontal bearing on the masonry, and at least every second joist must be securely anchored to the wall, as is the one shown. Usually galleries are made with straight fronts, but if it is desired that the seats should be arranged in concentric

rings, all facing the speaker, the joists may be placed so as to radiate from the center from which the seats are to be laid out.

The seats are arranged in steps, one above the other, and the framing for the steps must be built up on top of the joists, as shown in the figure. Horizontal pieces, *c c c* usually two by four or three by four in size, are nailed to the joists at one end, and at the other end are supported by upright pieces *d d d*. The uprights are either two by four pieces resting on top of the joists or strips of board, one inch to one and one-half inches thick, which are nailed to the sides of the joists and to the sides of the horizontal pieces. Both methods are shown in the figure. If boards are used, they should be placed on both sides of the joists. Great

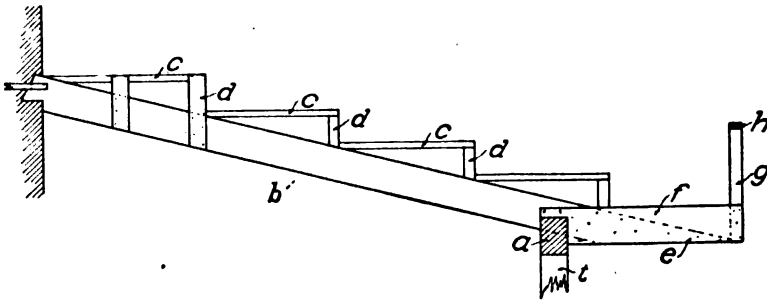


Fig. 193. Section of Gallery Frame.

care should be taken to see that the horizontal pieces are truly horizontal.

Balconies and galleries almost always project a considerable distance beyond the line of columns which support the lower ends of the joists. This projection varies from three feet to ten or twelve feet. If the overhang is not more than five feet, it can be supported by extending the joists beyond the girder, as is shown in Fig. 193. A strip of board, *e*, about one and one-half inches thick, is nailed to the side of the joist, and a furring piece *f* is nailed on top of the joist at its lower end to make it horizontal. The railing at the front of the gallery should be about two feet high, and may be framed with two by four posts, *g* having a cap *h* of the same size on top.

If the overhang of a gallery is more than about five feet it must usually be supported by a brace, as shown in Fig. 194.

The brace *a* is nailed to the post *b* and to the overhanging joist *c*, or may be framed into these pieces. If the construction is very light, the brace may consist of strips of board nailed to the sides of the joists, but in heavy work it must be a timber of a good size, well framed into both the post and the joists. These braces can

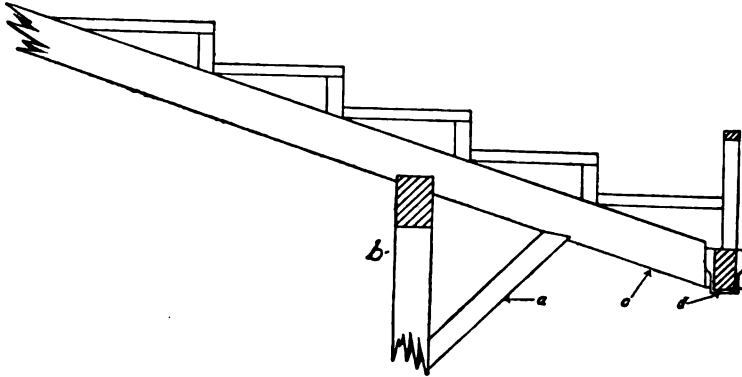


Fig. 194. Support for Extension Beyond Girder.

only be placed at points where there are posts, and to support the ends of the joists which come between the posts there must be a girder *d* running along the front of the gallery and supported by the braced cantilevers at the points where posts are placed.

Timber Trusses. In the discussion of roofs and roof framing, only those were considered which could be framed with ordi-

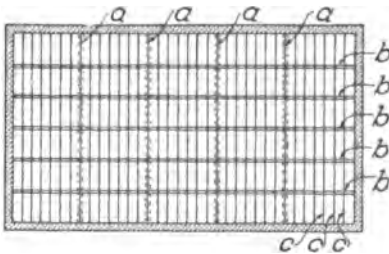


Fig. 196. Timber-Trussed Roof.

nary rafters, spaced from one foot to two feet apart, between centers, but it is very often necessary to build roofs of larger span, for which ordinary rafters, even if supported by dwarf walls and collar beams, are not sufficiently strong. In this case a different method of framing is employed.

Instead of a number of rafters

spaced fairly close together, and all of equal strength, we have a few heavy *trusses*, placed at intervals of ten feet or more, and spanning the entire distance between the side walls. On top of the trusses are laid *purlins* running parallel to the side walls, which

in their turn support the common rafters. There may be one or more purlins in each slope of the roof, depending upon the size of the span. This arrangement is shown in plan in Fig. 195, in which *a a* are the trusses, *b b* are the purlins, and *c c c* are the common rafters.

There are many different kinds of trusses which are in common use, for various kinds of buildings, differing from each other chiefly in the arrangement of the tension and compression pieces of which they are composed. Some are built entirely of timber, while in others timber is employed only for the compression pieces, and wrought iron or steel for the tension pieces. Fig. 196 shows what is known as a *king post* truss. Its distinguishing feature in the member *a*, called the *king post*; *b b b* are the purlins, and *e e* the rafters resting on them. Two different methods of placing

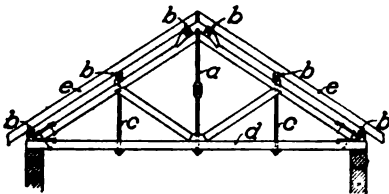


Fig. 196. King-Post Truss.

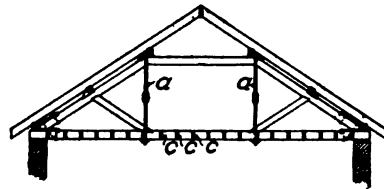


Fig. 197. Queen-Post Truss.

the purlins are illustrated in this figure. As will be readily seen, some of them are set so that their longer dimension, in cross section, is vertical, while others are set so that the longer dimension is at right angles to the rafters. Both of these methods are commonly employed. The tension members *c c* are merely for the support of the lower chord or *tie beam d*.

Fig. 197 shows a modification of the king post truss which is called the *queen post* truss. Here there are two *queen posts a a* in place of the single king post. This figure also shows how a floor or ceiling may be supported on the lower chord or *tie beam* of the truss. The joists *c c c* are hung from the chord by means of stirrup irons or patent hangers. The queen post truss is somewhat more popular in building work than is the king post truss, but both are frequently employed in halls, warehouses, and stables where an ornamental truss is not required, and also in churches and audience rooms where they are to be concealed by other finish.

In Fig. 198 is shown a *Fink* truss, which is a very popular form, especially for trusses built of steel. It has neither king post or queen posts, and the *tie beam* *a* is of iron instead of timber. It is a simple and cheap form of truss for any situation where

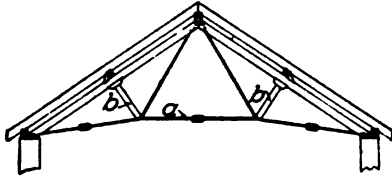


Fig. 198. Fink Truss.

there is no floor or ceiling to be carried by the lower chord. The struts *b b* may be of wood or of cast iron. It will be seen that the truss consists essentially of two trussed rafters set up against each other, with a tie rod *a* to take up the horizontal thrust.

Beside the forms of trusses described above, there are other forms which are used in churches and chapels where *open timber* work is required, and where they will not be concealed by other finish, but will be made ornamental in themselves. Among these the most common forms are the so-called *scissors* truss and the *hammer beam* truss.

The *scissors* truss is shown in Fig. 199. It has no tie beam, and therefore it may exert considerable thrust on the walls of the building, which must be taken care of by buttresses built up on the outside of the wall. This is perhaps the most simple form of truss which can be used when an open timber truss is required. All the parts are of wood. If desired, an iron tie rod may be inserted between the two wall bearings of the truss, so as to diminish the thrust on the walls, and this need not detract seriously from the appearance of the open timber work.

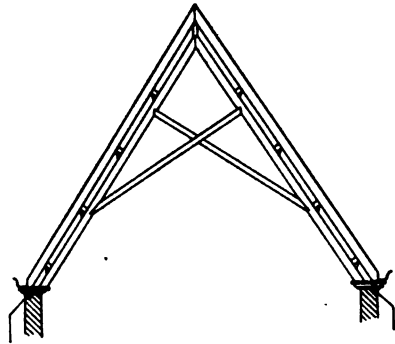


Fig. 199. Scissors Truss.

A very popular form of truss for use in churches is the *hammer beam* truss mentioned above. This is shown in Fig. 200. On the left is shown the framework for the truss, while on the right is shown the way in which it may be finished. Its characteristic feature is the *hammer beam* *a*.

The sizes of the pieces can only be determined by calculation or experience, and depend entirely upon the span of the truss and the loads to be carried, which are different for different parts of the country. It is common practice to insert a tie rod between the points *b* and *c* to take up some of the thrust which would otherwise come on the walls. All parts of the framework must be securely bolted or spiked together so as to give a strong, rigid foundation for the decoration, and this should be regarded merely as decoration and should not be considered as strengthening the truss in any way.

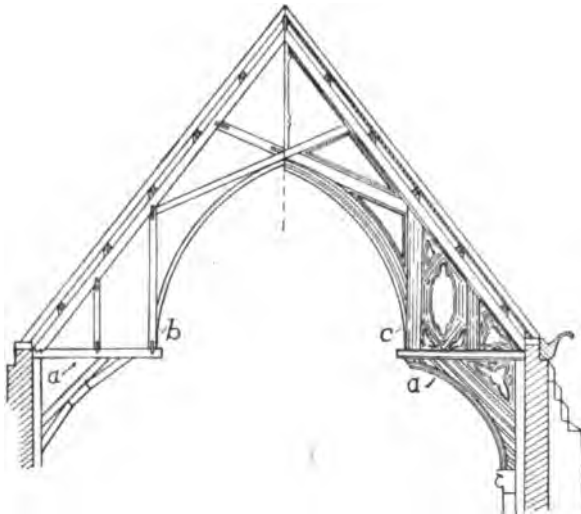


Fig. 200. Hammer Beam Truss.

Truss Details. There are several ways of supporting the purlins on wooden trusses, but the method illustrated in Fig. 201 is one of the best as well as the most frequently employed. A block of wood *a* is set up against the lower side of the purlin, and prevents it from turning about the corner *b*, which it has a tendency to do. The block is set into the chord of the truss to a depth sufficient to keep the purlin from sliding downward as it receives the weight from the rafters *e*. This figure also shows the most simple method of framing a strut into the chord of a truss. The strut *c* is set into the chord *d* far enough to hold it in place. If it is perpendicular to the chord, it need not be so set into it, if

the pieces are well nailed together, because in this case there is no tendency for the strut to slide along the chord. Care should be taken not to weaken the chord too much in cutting these mortises.

In Fig. 202 are shown the two most common methods of forming the joint between the top chord and the tie beam of a

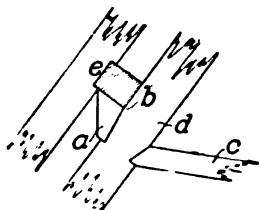


Fig. 201. Support for Purlins.

truss. The connection shown at A depends upon the bolts for its strength, while that shown at B depends upon the wrought iron straps *a*, which are bent so as to engage notches cut in the tie beam *b*. The piece *c* is very often added beneath the tie beam, at the bearing, to strengthen it at this point, where it is subject to considerable bending stress. The block *d* is merely for filling and to protect the bolts when they pass between the chord and the tie beam. It may be omitted in many cases. The plate *f* is placed between the nuts or bolt heads and the wood to prevent the crushing of the latter. Washers should be used with all bolts for this purpose.

Fig. 203 shows how the joint at the center of the tie beam of a king post truss, or any joint between two struts, may be formed. The tie beam is shown at *a*, and *b b* are the struts. The blocks *c*,

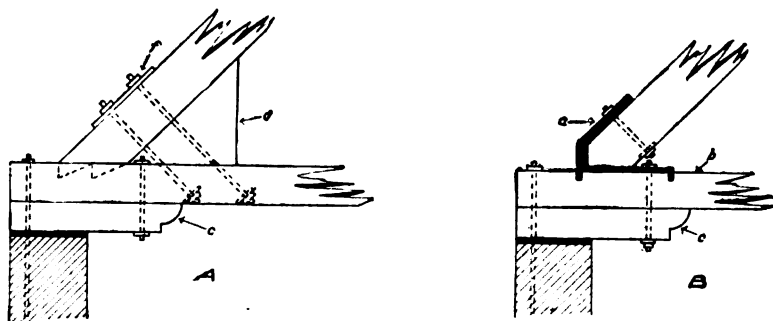


Fig. 202. Joints at Top Chord and Tie Beams.

set between the struts, receive the thrust from them. They should be notched into the tie beam *a*, deep enough to take care of any inequality between the thrusts from the two struts, which have a tendency to balance each other. This block is often made of cast

iron. It may be omitted altogether, in which case the struts will come close together and bear against each other. The rod *d* is the king post which supports the tie beam *a* at this point. It is often made of wood, and sometimes the struts *b b* are framed into it instead of being framed into the tie beam *a*.

Fig. 204 shows a form of connection for the peak of a truss, where the two top chords or *principal rafters* come together. The plate *a* acts as a tie to keep these members in place, as does the bent plate *b*, also. The plate *b*, moreover, prevents the crushing of the timber by the nut of the king post tie rod. The purlin *c* supports the rafters and is hollowed out at the bottom to admit the nut *d*. The two principal rafters bear against each other and must

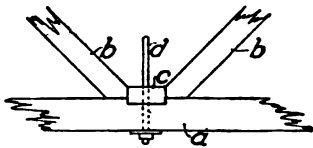


Fig. 203. Joint at Center of Tie Beam.

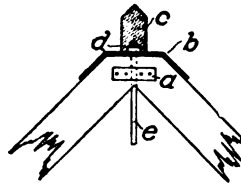


Fig. 204. Peak of Truss.

be cut so that the bearing area between them will be sufficient to prevent the crushing of the timber. In light trusses the king post *e* is often made of wood and is carried up between the principal rafters so that these members bear against it on each side. If this construction is adopted it must be remembered that the post is a tension member, and is held up by the principal rafters, and these pieces must be mortised into it in such a way as to accomplish this result.

There are a great many different ways of arranging the details for wooden trusses, each case usually requiring details peculiar to itself and unlike those for any other case. There are, therefore, no hard and fast rules which can be laid down to govern the design of these connections. A perfect understanding of the action of each piece and its relation to all the other pieces is the only thing which will insure an economical and appropriate design. The aim should always be to arrange the details so that there will be as little cutting of the pieces as possible, and so that the stresses may pass from one to the other without over-straining any part of the work.

Towers and Steeples. Towers are a very common feature in building construction, ranging in size from the small cupola seen almost invariably on barns and stables, to the high tapering spire which is the distinguishing mark of the country church.

They have roofs of various shapes, some in the form of pyramids, with four, eight, or twelve sides, some of conical form, and others bell-shaped or having a slightly concave surface.

The construction of all these forms of towers is much the same, consisting of an arrangement of posts and braces which

becomes more elaborate as the tower or steeple becomes larger. The bracing is the most important consideration, because the towers will be exposed to the full force of the wind and must be able to stand the great strain to which they are subjected.

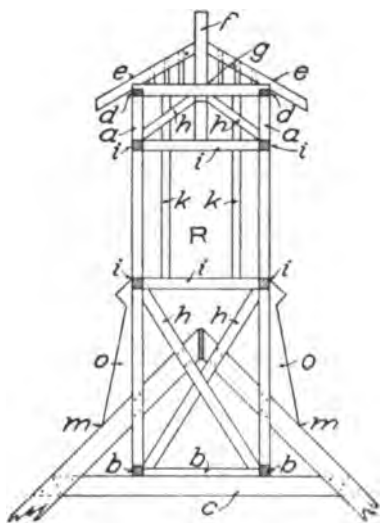


Fig 205. Frame for Cupola.

Fig. 205 shows a section through the frame of a simple cupola. It has posts *a a* at each corner, which rest at the bottom on the sills *b b*. The sills are supported on extra heavy collar beams *c*, which are very securely spiked to the rafters of the main roof *m m*. The corner posts extend clear up to the main plate

d d, which supports the rafters *e e* of the cupola. There are hip rafters at the corner of the roof, which bear at the top against a piece of scantling *f* placed in the center of the roof. This scantling extends above the roof surface far enough to receive some kind of metal finial which forms the finish at the extreme top of the cupola; and at the bottom it is firmly fastened to the tie *g* which is cut in between the plates. The braces *h h h h* stiffen the frames against the wind. Girts *i i* are cut in between the corner posts and form the top and bottom of the slat frame opening *R*, besides tying the posts together. The sides of the opening for the slat frame are formed by the vertical studs *k k*. The rafters of the

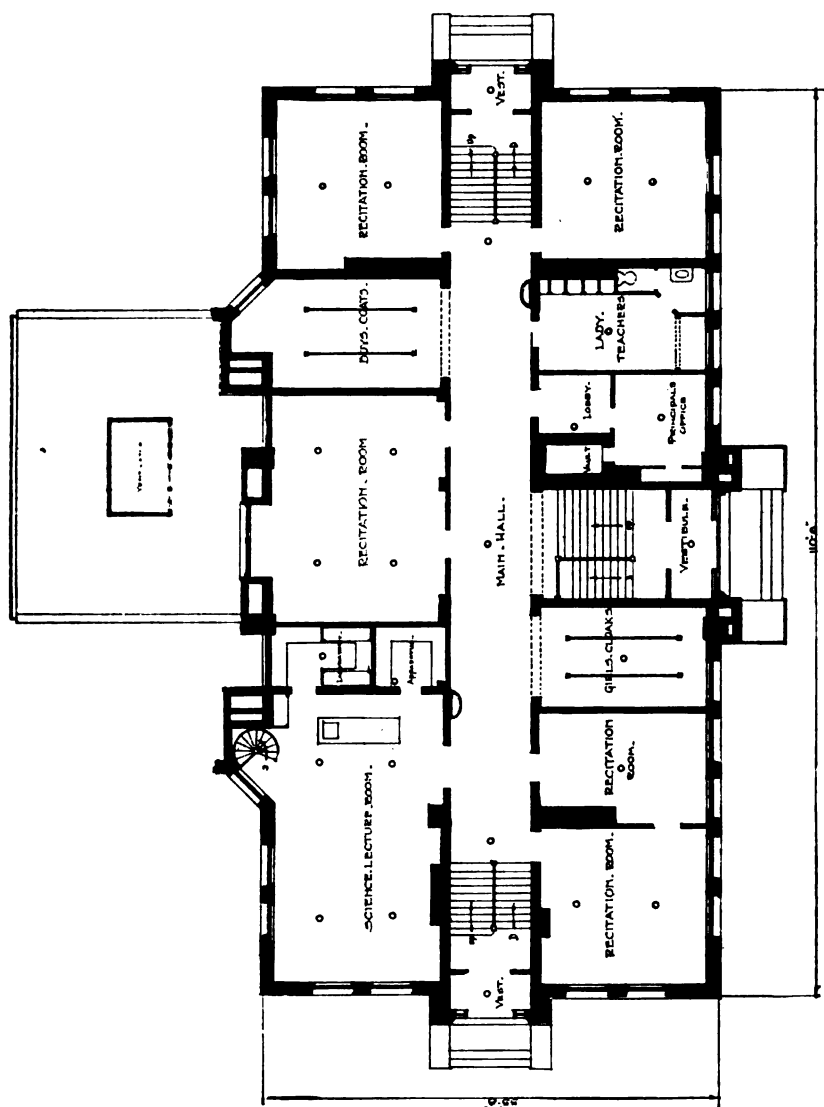




HIGH SCHOOL AT THREE RIVERS, MICH.

J. C. Llewellyn, Architect, Chicago, Ill.

Paving Brick Walls and Buff Bedford Trimmings; Tile Roof. Built in 1906.



PLAN OF FIRST FLOOR.

HIGH SCHOOL AT THREE RIVERS, MICH.

J. C. Llewellyn, Architect, Chicago, Ill.

Provision is Made in the Rear for a Future Auditorium. For Plans of Basement and Second Story, See Page 154.

main roof *m m* are placed close up against the corner posts on the outside, and the posts may be spiked to them. The pieces *o o* are of plank two inches thick, and are simply furring pieces placed at intervals of a foot and a half to two feet all around the cupola to give the desired shape to the bottom part. The size of the pieces will depend upon the size of the cupola. The posts may be four by four inches or six by six inches, and the braces, girts and intermediate studding may be three by four inches or four by six inches.

Other towers are framed in a manner similar to that described for cupolas. There is always a base or drum, with posts at the corners and with the walls filled in with studding, which supports a plate at the top. The rafters forming the tower roof rest at the foot on this plate, and at the top they bear against a piece of scantling which is carried down into the body of the tower for a considerable distance and is there fastened to a tie passing between rafters on opposite sides. This is shown in Fig. 206. The tie *a* is securely nailed to the rafters at each end, and to the scantling in the middle. The scantling is

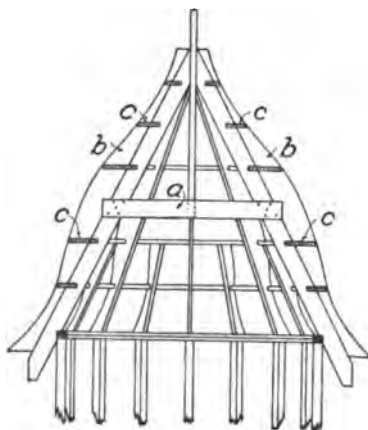


Fig. 206. Frame for Tower.

cut so as to have as many faces as the roof has sides, four for a square hip roof, eight for an octagon roof, and so on. Each face receives one of the hip rafters and the intermediate rafters are framed in between them. If the roof is conical or bell-shaped, as shown in the figure, the scantling at the top may be cylindrical in form. Although the roof shown is bell-shaped, the rafters are not cut to fit the curve. They are made straight and are filled out by furring pieces *b b*. Pieces of plank *c c* are cut in between the furring pieces, as shown, so as to give a nailing for the boarding, and they are cut to the shape of segments of circles, so as to form complete circles around the tower when they have been put in place. If a tower of this shape is to be built, leaving a number of

faces and hips, the curve of the hip rafters will not be the same as the curve shown by a section through one of the faces of the tower. In order to find the true curve for the hip rafters the same method is followed as was explained for the hip rafter in an ogee roof over a bay window, using the principle that any line drawn in the roof surface parallel to the plate is horizontal throughout its length. By this means any number of points in the curve of the hip rafter may be obtained and the curve for the hip may be drawn through them. Thus a pattern for the hip rafter may be obtained.

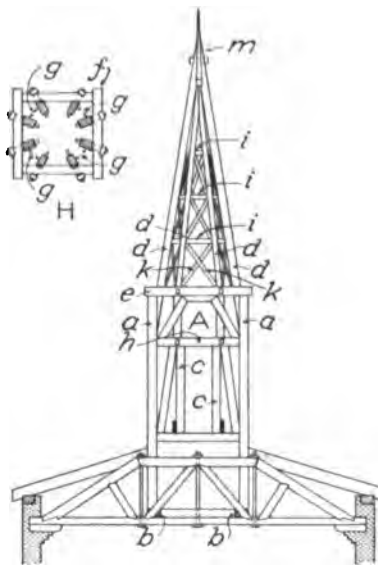


Fig. 207. Frame for Church Spire.

Fig. 207 shows the method of framing a church spire, or other high tapering tower. The drum *A* is square and is supported by the posts *a a*, one at each corner, which rest on the sills *b b*. The sills are supported by the roof trusses of the main roof. The corner posts extend the full height of the drum and are strongly braced in all four faces, with intermediate vertical studding *c c* between them to form the framework for these faces. The spire itself may rest on top of this square drum or there may be another eight- or twelve-sided drum constructed on top of the first on which the

spire may rest. This depends upon the design of the spire. The hip rafters *d d d d* do not rest directly on top of the drum, however, as this arrangement would not give sufficient anchorage for the spire. They are made so as to pass close inside the plate *e* at the top of the drum and are securely bolted to this plate with strong bolts. This is shown at *H* which is a plan of the top of the drum, showing the hip rafters in place. The plate is shown at *f* and the hip rafters at *g*. The rafters extend down into the body of the drum as far as the girt *h* (shown in the elevation) to which they are again securely spiked or bolted, being cut out at the foot so

as to fit against the girt. In this way a strong anchorage for the spire is obtained.

Horizontal pieces *i i i* are cut in between the hip rafters at intervals throughout the height of the spire, and braces *k k* halved together at the center where they cross each other are firmly nailed to the rafters at each end. These braces are needed only in lofty spires, which are likely to be exposed to high winds. At the top the hip rafters bear against a piece of scantling *m* the same as in the other towers. If a conical spire is called for in the design, the horizontal pieces *i i i* must be cut to the shape of segments of circles, and in this case the rafters are no longer hip rafters. The horizontal pieces *i i* will receive the boarding which will form a smooth conical surface.

The spire above the drum is usually framed on the ground before being raised to its final position. It may then be raised part way and supported by temporary staging while the top is finished and painted, after which it may be placed in position on top of the drum.

Domes. Timber domes have been built over many famous buildings, among which may be mentioned St. Paul's Cathedral at London, and the Hotel des Invalides at Paris. While these structures are domical in shape they are not, strictly speaking, domes, because they do not depend for support upon the same principle which is employed in the construction of masonry domes. They are, correctly speaking, arrangements of trusses of such a shape as to give the required domical form to the exterior of the roof.

Fig. 208 shows such a truss supported at either end on a masonry wall as shown. Fig. 209, which is a plan of the framing of this roof, shows how the trusses or *bents* may be arranged. There are two complete bents, *a b* and *c d*, like the one shown in the elevation, Fig. 208, which intersect each other at the center. The king post *a*, in the elevation, is common to both bents, and the tie beams *b* are halved together where they cross. These two bents divide the roof surface into four quarters which are filled in by shorter ribs, as indicated in the plan, Fig. 209. The posts *c* in Fig. 208 carry all the weight of the roof to the walls and are braced by means of the pieces *d*. The rounded shape is given to the exterior and interior of the bent by pieces of plank bent into posi-

tion as shown. The whole is covered with boarding which is cut to a special shape so that it can be bent into place. The methods of applying the boarding to domical roofs will be explained in connection with other rough boarding.

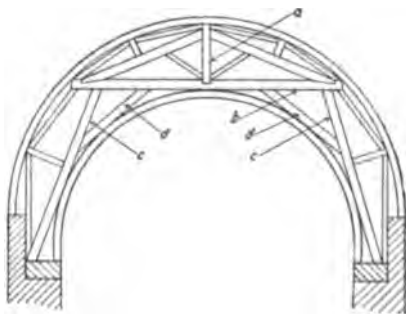


Fig. 208. Frame for Dome.

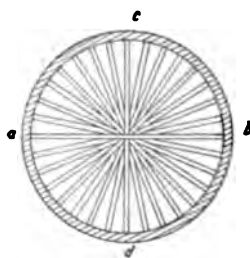


Fig. 209. Plan of Dome Framing.

The arrangement of trusses or bents described above is suitable for a plain domical roof without a lantern or cupola on top, but very frequently this feature is present in the design, and the roof must be framed to allow for it. There are several different ways of arranging the trusses so as to leave an opening in the center of the roof for the lantern. Fig. 210 shows a very good

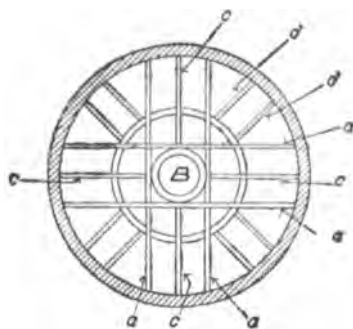


Fig. 210. Plan of Dome Framing with Central Opening.

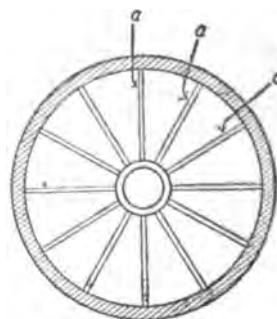


Fig. 211. Plan of Dome Framing with Opening.

arrangement. Four trusses, *a a a a*, span the entire distance between the walls, and are placed as shown in the figure, so as to leave the opening *B* in the center. Four half trusses *c c c c* are

inserted between them, as shown, and eight shorter ribs *d d* are employed to fill in the rest of the space.

Fig. 211 shows another arrangement, providing for a lantern at the center. There are a number of ribs, *a a a*, twelve in the figure, all radiating from the center where there is a circular opening for the lantern or cupola. In Fig. 212 is shown a section through a domical roof framed in this way, showing an elevation of one of the ribs. The rib is so constructed as to be entirely contained in the restricted space between the lines of the exterior and interior of the roof.



Fig. 212. Section of Dome Framing.

Pendentives. In the preceding paragraphs we have considered the subject of domical roofs covering buildings of circular plan, which is the simplest possible case, but unfortunately not the most usual one. It very often happens that a domical roof must be erected over a building which is square or rectangular in plan, in which case a new and difficult problem must be considered, namely, that of the pendentives. A horizontal section taken through a dome must in every case show a circle or possibly an ellipse.

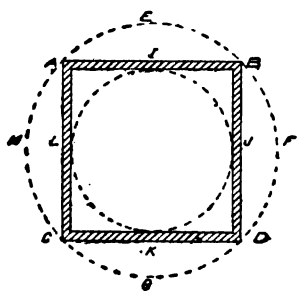


Fig. 213. Dome on Rectangular Walls.

If, then, we consider the horizontal section cut from a domical roof by the plane of the top of the wall, it must usually be a circle and cannot exactly coincide with the section cut from the wall of the building by the same plane, unless the building is circular in plan. This is shown in Fig. 213 in which A B C D represents the section cut from the wall of the building by a horizontal plane, and the circle E F G H represents the section which would be cut from a domical roof covering the building if the framing for the dome were carried down to meet this plane all the way around.

In order to cover every part of the building, the dome must be large enough to include the corners, and if made sufficiently large for this it must overhang the side walls of the building, by an amount A E B on each side, if the framing is carried down to

the same horizontal plane all the way around. Horizontal sections taken through the dome at intervals throughout its height, however, show smaller and smaller circles as they are taken nearer and nearer to the top of the dome. Some one of these sections will cut out from the dome a circle, which will appear in plan as though it were inscribed in the square formed by the walls of the building. Such a circle is shown at I J K L in Fig. 213. A dome built up with this circle as a base would not cover the corners of the building, so that the triangular spaces like A I L would be kept open. These triangular spaces, or rather the coverings over them, are called the pendentives. Fig. 214 shows in perspective the outline of four pendentives E D H, H C G, etc.

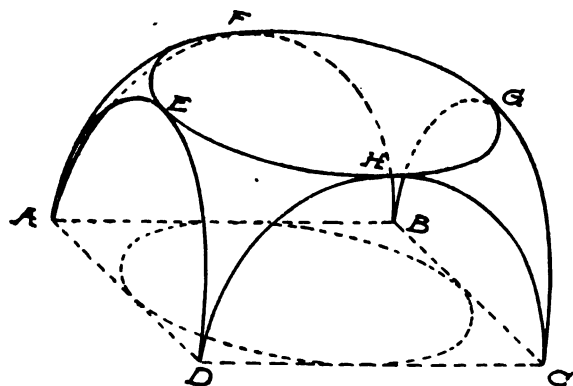


Fig. 214. Pendentives.

We have seen that a dome built up on the circumscribed circle as a base is too large, while a dome built up on the inscribed circle is too small and will not completely cover the building. To overcome this difficulty it is customary to erect a dome on the smaller or inscribed circle as a base, and to extend the ribs so as to fill up the corners and form a framework for the pendentives. This is shown in Fig. 215 which is a plan of the framework for a domical roof. The ribs will be of different lengths and will intersect the inside face of the wall at different heights, because as they are extended outward they must also be extended downward. Each one will be curved if the dome is spherical, and straight if the dome is conical. The upper ends of the ribs bear against the curb A leaving a circular opening for a lantern or cupola. The

lower ends may be supported on a masonry wall, or may rest on curved wooden plates, as shown in Fig. 216. This is an elevation of a conical dome and shows the straight ribs *a b*, *c d*, etc.

Fig. 217 shows an elevation of a spherical dome which has curved ribs, *a b*, *c d*, etc., as shown. Each of these ribs must be

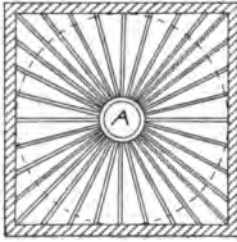


Fig. 215. Plan of Frame for Domical Roof.

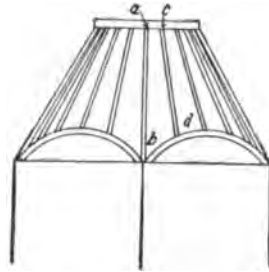


Fig. 216. Elevation of Conical Dome.

bent or shaped to the segment of a circle, in order that their edges may lie in a spherical surface.

If the design calls only for a domical *ceiling* and the exterior may be of some other form, then only the inside edges of the ribs need be dressed to correspond with a spherical or conical surface, in order that they may receive the lathing or furring, and the outside may be left rough and a false roof of any desired shape may be built. If the *exterior* must be of domical form while on the interior there is a suspended or false ceiling of some kind, then only the outside edges of the ribs must lie in the conical or spherical surface, so as to receive the roof boarding, while the inside edges may be left rough or shaped to any other form. If both the exterior and interior must be domical, then both the inside and outside edges of the ribs must be dressed so as to lie in the domical surface.



Fig. 217. Elevation of Spherical Dome.

Conical domes are very uncommon, but they are sometimes used. A conical dome is much easier to frame than a spherical dome because the ribs are straight. The shape of the curved plate

which supports the lower ends of the ribs may be easily determined, since it must conform to the line of intersection between the conical or spherical surface of the dome, and the plane of the face of the wall.

Niches. Niches are of common occurrence in building work, especially in churches, halls and other important structures. Sometimes they are simply recesses in the wall with straight corners and a square head, but more often they are semicircular in form, with spherical heads in which case the framing becomes a matter of some difficulty. The framing of the wall for a semicircular niche is the easiest part of the work, since all the pieces may be straight, but for the framing of the head the ribs must be bent or shaped to conform to the surface of a sphere.

Fig. 218 shows in plan the way in which the vertical studding of the walls must be placed. The inside edges must lie in a cylindrical surface, and will receive the lathing and plastering.

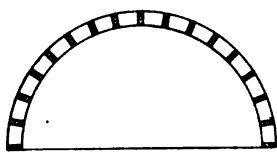


Fig. 218. Plan of Vertical Studding for Niche.

There must be a curved sole piece for them to rest upon at the bottom and a cap at the top. The cap is shown at A B in Fig. 219, which is an elevation of the *cradling* or framing for the niche. This figure shows how the ribs for the head of the niche must be bent. The ribs and vertical studs must be spaced

not farther than twelve inches apart, center to center.

The form of niche described above is the most common one for large niches intended to hold full size casts or other pieces of statuary, but smaller ones for holding busts and vases are quite common. These are often made in the form of a quarter sphere or some smaller segment of a sphere, with a flat base or floor and a spherical head, as is shown in section in Fig. 220. They are framed with curved ribs in the same way as described above, and finished with lathing and plastering.

Vaults and Groins. Although vaulted roofs are an outgrowth of masonry construction, and are almost always built of brick or stone, they are occasionally of timber, and in any case a timber centering must be built for them. A vault may be described as the surface generated by a curved line as the line moves through

space, and in accordance with this definition there are vaults of all kinds, semicircular or *barrel* vaults, elliptical vaults, conical vaults, and many others.

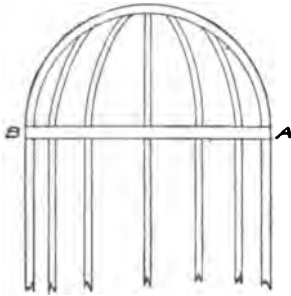


Fig. 219. Elevation of Cradling for Niche.

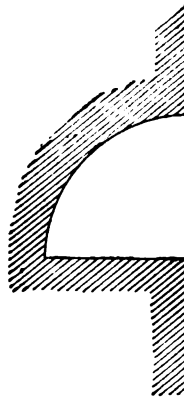


Fig. 220. Section of Quarter-Sphere Niche.

In Fig. 221 is shown in outline a simple semicircular or *barrel* vault, known as well by the name *cylindrical vault*. The point A where the straight vertical wall ends and the curved surface begins is called the *springing point*. The point B is the crown of the vault. The distance between the springing points on opposite sides of the vault is the *span*, and the vertical distance between the springing point and the crown B is the *rise*.

It may easily be seen how a barrel vault, or a vault of any kind, may be framed, with curved ribs spaced from one foot to eighteen inches apart on centers, and following the outline of a section of the vault. If the framework is intended to be permanent and to form the body of the vault itself, then the inner edges of the ribs must lie in the surface of the vault and must be covered with lathing and plastering. If only a centering is being built, on which it is intended that a masonry vault shall be supported temporarily, then the outer edges of the ribs must conform to the vaulted surface and must be covered with rough boarding to receive the masonry.

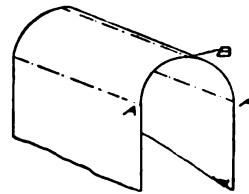


Fig. 221. Barrel Vault.

Fig. 222 shows one method of forming the cradling for a groined ceiling, but there is another which is also in common use. This is shown in Fig. 223. There are four curved ribs $a b$, $b d$, $c d$, and $c a$ which span the distances from corner to corner around the space to be covered. The diagonal ribs $a d$ and $c b$ are also employed as in the first method. Straight horizontal purlins are supported on these ribs, running parallel to the direction of the vaults, as shown in the figure. They are spaced about sixteen inches apart and form the framework for the ceiling.

The only difficult problem in connection with groined ceilings is to find the shape of the diagonal rib. This rib, as has been explained above, must coincide with the line of intersection of the vaults. The problem, then, is to find the true shape of the diagonal rib.

Let us consider the two vaults shown in plan in Fig. 224. They are not of the same span, but they will be of the same height if we wish to have a common groin and not a Welsh groin; so if one is semi-circular the other must be elliptical. Elevations of ribs in each vault are shown at A and B and the diagonal ribs are shown in plan at $a c$ and $b d$. It is easy to find the plan of these ribs because they

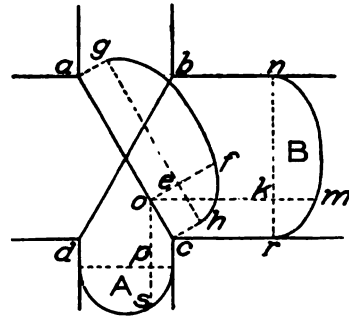


Fig. 224. Plan of Intersecting Vaults.

must pass from corner to corner diagonally. To find the elevation we must use the same principle that was employed in finding the position of the valley rafter and the shape of the curved hip rafter for an ogee roof, namely, any line drawn in the roof or ceiling surface parallel to the plate or side walls, must be horizontal, and all points in it must be at the same elevation.

We start with the assumption that one of the vaults is semi-circular, as shown in elevation at A, Fig. 224. Taking any line in the vaulted surface, shown in plan, as the line $s p o$, we produce it until it intersects the plan of the diagonal rib $a c$ at the point o . This point must be the plan of one point in the line of intersection of the vaulted surfaces.

The elevation of the point *o* above the springing line of the vaults is shown by the distance *p s*, since the line *s p o* is exactly horizontal throughout. This distance is laid off at *e f* with the line *g e h* representing the horizontal plane which contains the springing lines of the vaults. The point *h* is the point from which the diagonal rib starts. The point *f*, as we have seen is another point in the curve, and we can by a similar process locate as many points as we need. This will enable us to draw the complete curve *g f h* of the line in which the vaults intersect, and to which the diagonal rib must conform.

By continuing the line from the point *o* at right angles to its former direction and parallel to the wall line we may obtain the point *k* which is a plan of one point in the surface of the elliptical vault. The elevation of this point also above the springing lines must be the same as for the point *s* and may be laid off, as shown at *k m*. By finding other points in a similar way the curve *n m r* of the elliptical vault may be readily determined.





HALL AND STAIRCASE IN HOUSE AT WOLLASTON, MASS.
Frank Chouteau Brown, Architect

STAIR-BUILDING

Introductory. In the following instructions in the art of Stair-building, it is the intention to adhere closely to the practical phases of the subject, and to present only such matter as will directly aid the student in acquiring a practical mastery of the art.

Stair-building, though one of the most important subjects connected with the art of building, is probably the subject least understood by designers and by workmen generally. In but few of the plans that leave the offices of Architects, are the stairs properly laid down; and many of the books that have been sent out for the purpose of giving instruction in the art of building, have this common defect—that the body of the stairs is laid down imperfectly, and therefore presents great difficulties in the construction of the rail.

The stairs are an important feature of a building. On entering a house they are usually the first object to meet the eye and claim the attention. If one sees an ugly staircase, it will, in a measure, condemn the whole house, for the first impression produced will hardly afterwards be totally eradicated by commendable features that may be noted elsewhere in the building. It is extremely important, therefore, that both designer and workman shall see that staircases are properly laid out.

Stairways should be commodious to ascend—inviting people, as it were, to go up. When winders are used, they should extend past the spring line of the cylinder, so as to give proper width at the narrow end (see Fig. 72) and bring the rail there as nearly as possible to the same pitch or slant as the rail over the square steps. When the hall is of sufficient width, the stairway should not be less than four feet wide, so that two people can conveniently pass each other thereon. The height of riser and width of tread are governed by the staircase, which is the space allowed for the stairway; but, as a general rule, the tread should not be less than nine inches wide, and the riser should not be over eight inches high. Seven-inch riser

and eleven-inch tread will make an easy stepping stairway. If you increase the width of the tread, you must reduce the height of the riser. The tread and riser together should not be over eighteen inches, and not less than seventeen inches. These dimensions, however, cannot always be adhered to, as conditions will often compel a deviation from the rule; for instance, in large buildings, such as hotels, railway depots, or other public buildings, treads are often made 18

inches wide, having risers of from $2\frac{1}{2}$ inches to 5 inches depth.

Definitions. Before proceeding further with the subject, it is essential that the student make himself familiar with a few of the terms used in stair-building.

The term *rise and run* is often used, and indicates certain dimensions of the stairway. Fig.

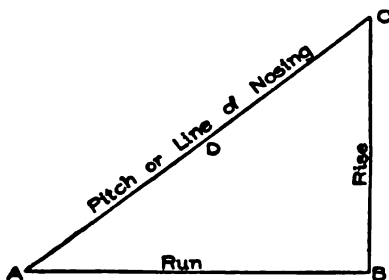


Fig. 1. Illustrating Rise, Run, and Pitch.

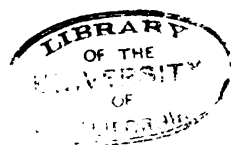
1 will illustrate exactly what is

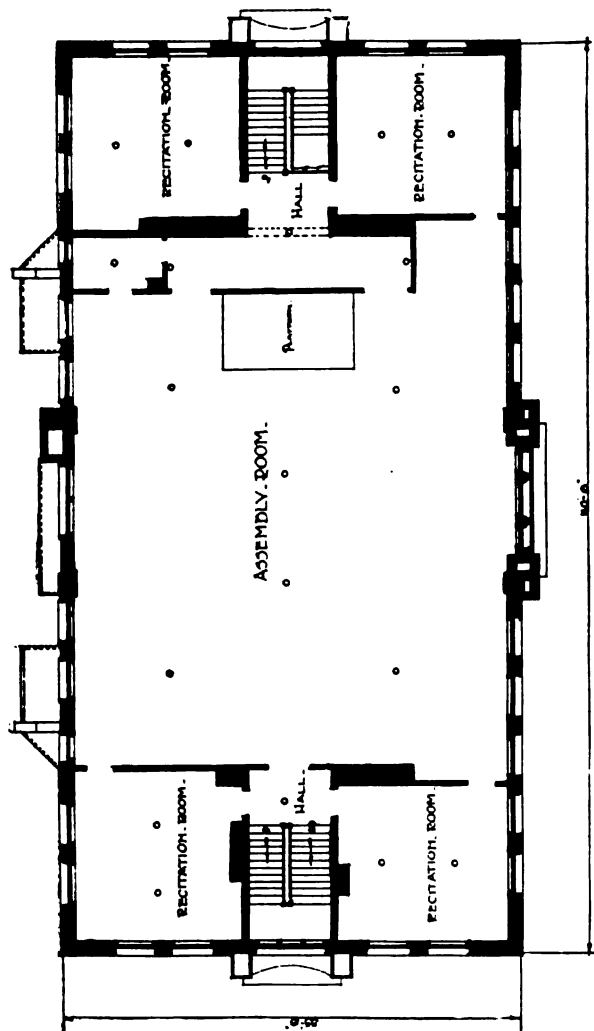
meant; the line *AB* shows the *run*, or the length over the floor the stairs will occupy. From *B* to *C* is the *rise*, or the total height from *top* of lower floor to *top* of upper floor.* The line *AC* is the *pitch* or *line of nosings*, showing the angle of inclination of the stairs. On the three lines shown—the *run*, the *rise*, and the *pitch*—depends the whole system of stair-building.

The *body* or *staircase* is the room or space in which the stairway is contained. This may be a space including the width and length of the stairway only, in which case it is called a *close stairway*, no rail or baluster being necessary. Or the stairway may be in a large apartment, such as a passage or hall, or even in a large room, openings being left in the upper floors so as to allow road room for persons on the stairway, and to furnish communication between the stairways and the different stories of the building. In such cases we have what are known as *open stairways*, from the fact that they are not closed on both sides, the steps showing their ends at one side, while on the other side they are generally placed against the wall.

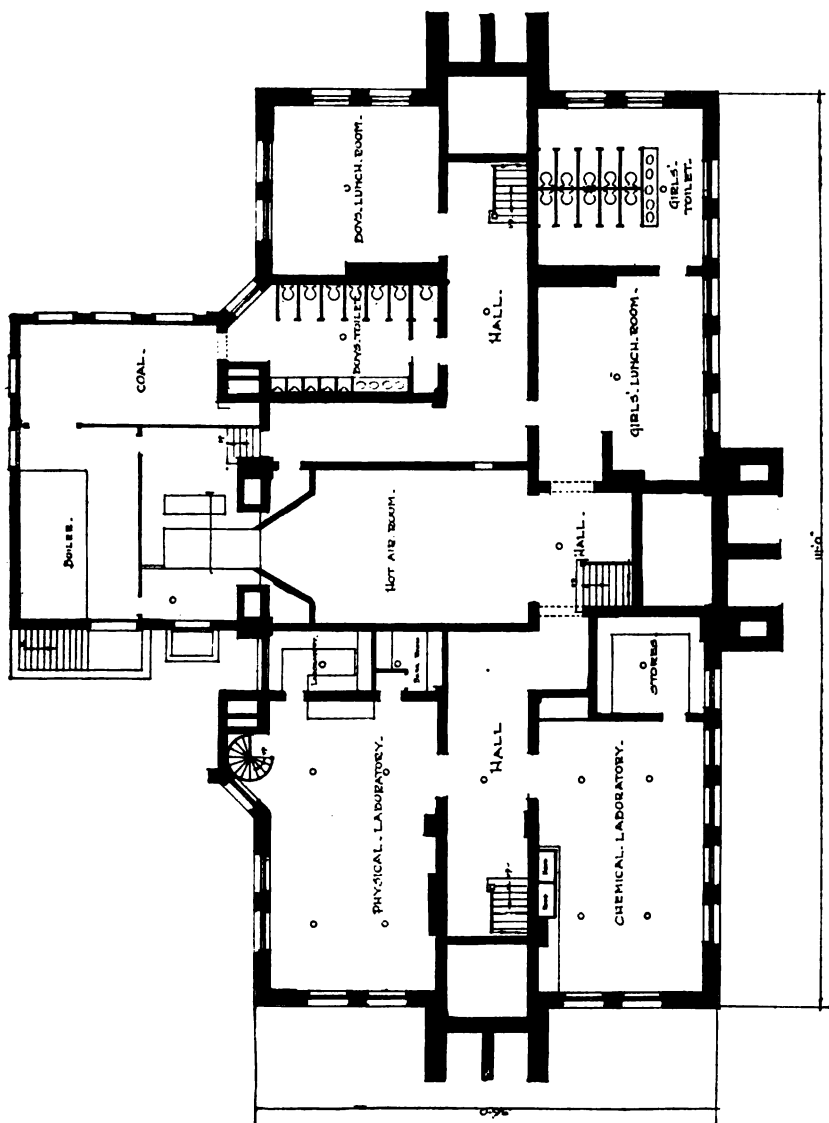
Sometimes stairways are left open on both sides, a practice not

*NOTE.—The measure for the rise of a stairway must always be taken from the *top* of one floor to the *top* of the next.





PLAN OF SECOND FLOOR.
 HIGH SCHOOL AT THREE RIVERS, MICH.
 J. C. Llewellyn, Architect, Chicago, Ill.
 Basement Plan Shown on Opposite Page



PLAN OF BASEMENT.

HIGH SCHOOL AT THREE RIVERS, MICH.

J. C. Llewellyn, Architect, Chicago, Ill.

Second-Floor Plan Shown on Opposite Page, For Exterior and Plan of First Floor, See Page 188



uncommon in hotels, public halls, and steamships. When such stairs are employed, the openings in the upper floor should be well *trimmed* with joists or beams somewhat stronger than the ordinary joists used in the same floor, as will be explained further on.

Tread. This is the horizontal, upper surface of the step, upon which the foot is placed. In other words, it is the piece of material that forms the step, and is generally from $1\frac{1}{2}$ to 3 inches thick, and made of a width and length to suit the position for which it is intended. In small houses, the treads are usually made of $\frac{7}{8}$ -inch stuff.

Riser. This is the vertical height of the step. The riser is generally made of thinner stuff than the tread, and, as a rule, is not so heavy. Its duty is to connect the treads together, and to give the stairs strength and solidity.

Rise and Run. This term, as already explained, is used to indicate the horizontal and vertical dimensions of the stairway, the *rise* meaning the height from the top of the lower floor to the top of the second floor; and the *run* meaning the horizontal distance from the face of the first riser to the face of the last or top riser, or, in other words, the distance between the face of the first riser and the point where a plumb line from the face of the top riser would strike the floor. It is, in fact, simply the distance that the treads would make if put side by side and measured together—without, of course, taking in the nosings.

Suppose there are fifteen treads, each being 11 inches wide; this would make a run of $15 \times 11 = 165$ inches = 13 feet 9 inches. Sometimes this distance is called the *going* of the stair; this, however, is an English term, seldom used in America, and when used, refers as frequently to the length of the single tread as it does to the *run* of the stairway.

String-Board. This is the board forming the side of the stairway, connecting with, and supporting the ends of the steps. Where the steps are *housed*, or grooved into the board, it is known by the term *housed string*; and when it is cut through for the tread to rest upon, and is mitered to the riser, it is known by the term *cut and mitered string*. The dimensions of the lumber generally used for the purpose in practical work, are $9\frac{1}{2}$ inches width and $\frac{7}{8}$ inch thickness. In the first-class stairways the thickness is usually $1\frac{1}{8}$ inches, for both front and wall strings.

Fig. 2 shows the manner in which most stair-builders put their risers and treads together. *T* and *T* show the treads; *R* and *R*, the risers; *S* and *S*, the string; *O* and *O*, the

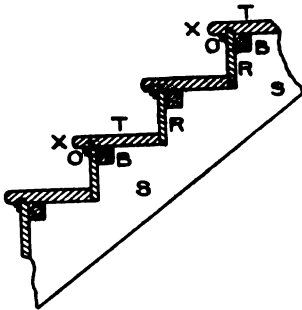


Fig. 2. Common Method of Joining Risers and Treads.

cove mouldings under the nosings *X* and *X*. *B* and *B* show the blocks that hold the treads and risers together; these blocks should be from 4 to 6 inches long, and made of very dry wood; their section may be from 1 to 2 inches square. On a tread 3 feet long, three of these blocks should be used at about equal distances apart, putting the two outside ones about 6 inches from the strings.

They are glued up tight into the angle.

First warm the blocks; next coat two adjoining sides with good, strong glue; then put them in position, and nail them firmly to both tread and riser. It will be noticed that the riser has a lip on the upper edge, which enters into a groove in the tread. This lip is generally

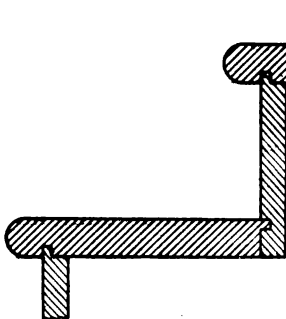


Fig. 3. Vertical Section of Stair Steps.

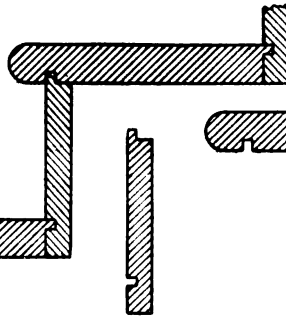


Fig. 4. End Section of Riser.

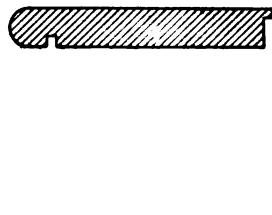


Fig. 5. End Section of Tread.

about $\frac{3}{8}$ inch long, and may be $\frac{3}{8}$ inch or $\frac{1}{2}$ inch in thickness. Care must be taken in getting out the risers, that they shall not be made too narrow, as allowance must be made for the lip.

If the riser is a little too wide, this will do no harm, as the over-width may hang down below the tread; but it must be cut the exact width where it rests on the string. The treads must be made the exact width required, before they are grooved or have the nosing

worked on the outer edge. The lip or tongue on the riser should fit snugly in the groove, and should *bottom*. By following these last instructions and seeing that the *blocks* are well glued in, a good solid job will be the result.

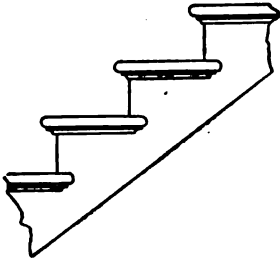


Fig. 6. Side Elevation of Finished Steps with Return Nosings and Cove Moulding.

Fig. 3 is a vertical section of stair steps in which the risers are shown tongued into the under side of the tread, as in Fig. 2, and also the tread tongued into the face of the riser. This last method is in general use throughout the country. The stair-builder, when he has steps of this kind to construct, needs to be very careful to secure the exact width

for tread and riser, including the tongue on each. The usual method, in getting the parts prepared, is to make a pattern showing the end section of each. The millman, with these patterns to guide him, will be able to run the material through the machine without any danger of leaving it either too wide or too narrow; while, if he is left to himself without patterns, he is liable to make mistakes. These patterns are illustrated in Figs. 4 and 5 respectively, and, as shown, are merely end sections of riser and tread.

Fig. 6 is a side elevation of the steps as finished, with return nosings and cove moulding complete.

A front elevation of the finished step is shown in Fig. 7, the nosing and riser returning against the base of the newel post. Often the newel post projects past the riser, in front; and when such is the case, the riser and nosing are cut square against the base of the newel.

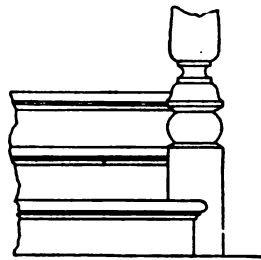


Fig. 7. Front Elevation of Finished Steps.

Fig. 8 shows a portion of a cut and mitered string, which will give an excellent idea of the method of construction. The letter *O* shows the nosing, *F* the return nosing with a bracket terminating against it. These brackets are about $\frac{5}{16}$ inch thick, and are *planted* (nailed) on the string; the brackets miter with the ends of the risers; the ends of the brackets which miter with the risers, are

to be the same height as the riser. The lower ends of two balusters are shown at *G G*; and the dovetails or mortises to receive these are shown at *E E*. Generally two balusters are placed on each tread, as shown; but there are sometimes instances in which three are used, while in others only one baluster is made use of.

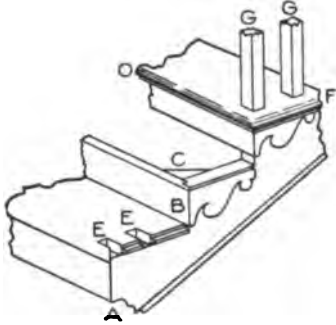


Fig. 8. Portion of a Cut and Mitered String. Showing Method of Constructing Stairs.

An end portion of a cut and mitered string is shown in Fig. 9, with part of the string taken away, showing the *carriage*—a rough piece of lumber to which the finished string is nailed or otherwise fastened. At *C* is shown the return nosing, and the manner in which the work is finished. A rough bracket is sometimes nailed on the carriage, as shown at *D*, to support the tread. The balusters are shown dovetailed into the ends of the treads, and are either glued or nailed in place, or both. On the lower edge of string, at *B*, is a return bead or moulding. It will be noticed that the rough carriage is *cut in* snugly against the floor joist.

Fig. 10 is a plan of the portion of a stairway shown in Fig. 9. Here the position of the string, bracket, riser, and tread can be seen. At the lower step is shown how to miter the riser to the string; and at the second step is shown how to miter it to the bracket.

Fig. 11 shows a quick method of marking the ends of the treads for the dovetails for balusters. The templet *A* is made of some thin material, preferably zinc or hardwood. The dovetails are outlined as shown, and the intervening portions of the material are cut away, leaving the dovetail portions solid. The templet is then nailed or screwed to a gauge-block *E*,

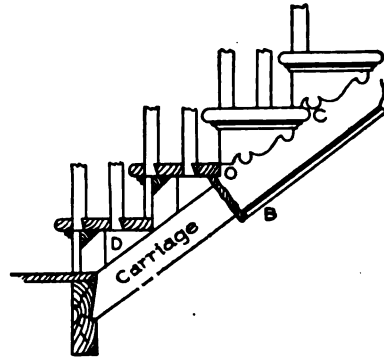


Fig. 9. End Portion of Cut and Mitered String, with Part Removed to Show Carriage.

when the whole is ready for use. The method of using is clearly indicated in the illustration.

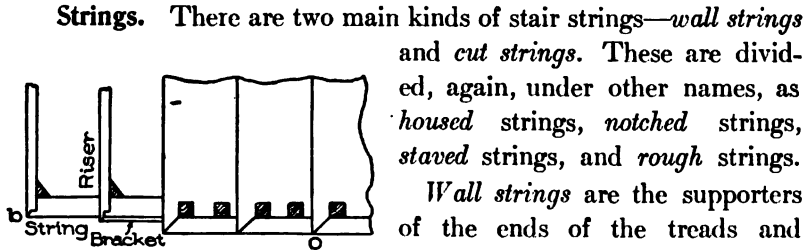


Fig. 10. Plan of Portion of Stair.

Strings. There are two main kinds of stair strings—*wall strings* and *cut strings*. These are divided, again, under other names, as *housed strings*, *notched strings*, *staved strings*, and *rough strings*.

Wall strings are the supporters of the ends of the treads and risers that are against the wall; these strings may be at both ends of

the treads and risers, or they may be at one end only. They may be *housed* (grooved) or left solid. When housed, the treads and risers are keyed into them, and glued and blocked. When left solid, they have a rough string or carriage spiked or screwed to them, to lend additional support to the ends of risers and treads. Stairs made after this fashion are generally of a rough, strong kind, and are especially adapted for use in factories, shops, and warehouses, where strength and rigidity are of more importance than mere external appearance.

Open strings are outside strings or supports, and are cut to the proper angles for receiving the ends of the treads and risers. It is over a string of this sort that the rail and balusters range; it is also on such a string that all nosings return; hence, in some localities, an open string is known as a *return string*.

Housed strings are those that have grooves cut in them to receive the ends of treads and risers. As a general thing, wall strings are housed. The housings are made from $\frac{3}{8}$ to $\frac{1}{2}$ inch deep, and the lines at top of tread and face of riser are made to correspond with the lines of riser and tread when in position. The back lines of the housings are so located that a taper wedge may be driven in so as to force the tread and riser close to the face shoulders, thus making a tight joint.

Rough strings are cut from undressed plank, and are used for strengthening the stairs. Sometimes a combination of rough-cut strings is used for circular or geometrical stairs, and, when framed together, forms the support or carriage of the stairs.

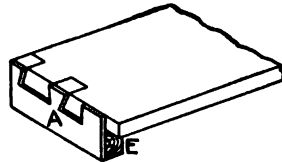


Fig. 11. Templet Used to Mark Dovetail Cuts for Balusters.

Staved strings are built-up strings, and are composed of narrow pieces glued, nailed, or bolted together so as to form a portion of a cylinder. These are sometimes used for circular stairs, though in ordinary practice the circular part of a string is a part of the main string bent around a cylinder to give it the right curve.

Notched strings are strings that carry only treads. They are generally somewhat narrower than the treads, and are housed across their entire width. A sample of this kind of string is the side of a common step-ladder. Strings of this sort are used chiefly in cellars, or for steps intended for similar purposes.

Setting Out Stairs. In setting out stairs, the first thing to do is to ascertain the locations of the first and last risers, with the height of the story wherein the stair is to be placed. These points should be marked out, and the distance between them divided off equally, giving the number of steps or treads required. Suppose we have between these two points 15 feet, or 180 inches. If we make our treads 10 inches wide, we shall have 18 treads. It must be remembered that *the number of risers is always one more than the number of treads*, so that in the case before us there will be 19 risers.

The height of the story is next to be exactly determined, being taken on a rod. Then, assuming a height of riser suitable to the place, we ascertain, by division, how often this height of riser is contained in the height of the story; the quotient, if there is no remainder, will be the number of risers in the story. Should there be a remainder on the first division, the operation is reversed, the number of inches in the height being made the dividend, and the before-found quotient, the divisor. The resulting quotient will indicate an amount to be added to the former assumed height of riser for a new trial height. The remainder will now be less than in the former division; and if necessary, the operation of reduction by division is repeated, until the height of the riser is obtained to the thirty-second part of an inch. These heights are then set off on the story rod as exactly as possible.

The *story rod* is simply a dressed or planed pole, cut to a length exactly corresponding to the height from the top of the lower floor to the top of the next floor. Let us suppose this height to be 11 feet 1 inch, or 133 inches. Now, we have 19 risers to place in this space, to enable us to get upstairs; therefore, if we divide 133 by 19, we get 7 without any remainder. Seven inches will therefore be the

width or height of the riser. Without figuring this out, the workman may find the exact width of the riser by dividing his story rod, by means of pointers, into 19 equal parts, any one part being the proper width. It may be well, at this point, to remember that *the first riser must always be narrower than the others*, because the thickness of the first tread must be taken off.

The width of treads may also be found without figuring, by pointing off the *run* of the stairs into the required number of parts; though, where the student is qualified, it is always better to obtain the width, both of treads and of risers, by the simple arithmetical rules.

Having determined the width of treads and risers, a *pitch-board* should be formed, showing the angle of inclination. This is done by cutting a piece of thin board or metal in the shape of a right-angled triangle, with its base exactly equal to the run of the step, and its perpendicular equal to the height of the riser. It is a general maxim, that the greater the breadth of a step or tread, the less should be the height of the riser; and, conversely, the less the breadth of a step, the greater should be the height of the riser. The proper relative dimensions of treads and risers may be illustrated graphically, as in Fig. 12.

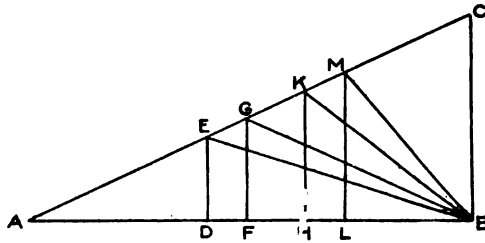


Fig. 12. Graphic Illustration of Proportional Dimensions of Treads and Risers.

In the right-angle triangle ABC , make AB equal to 24 inches, and BC equal to 11 inches—the standard proportion. Now, to find the riser corresponding to a given width of tread, from B , set off on AB the width of the tread, as BD ; and from D , erect a perpendicular DE , meeting the hypotenuse in E ; then DE is the height of the riser; and if we join B and E , the angle DBE is the angle of inclination, showing the slope of the ascent. In like manner, where BF is the width of the tread, FG is the riser, and BG the slope of the stair. A width of tread BH gives a riser of the height of HK ; and a width of tread equal to BL gives a riser equal to LM .

In the opinion of many builders, however, a better scheme of proportions for treads and risers is obtained by the following method:

Set down two sets of numbers, each in arithmetical progression—the first set showing widths of tread, increasing by inches; the other showing heights of riser, decreasing by half-inches.

TREADS, INCHES	RISERS, INCHES
5	9
6	8½
7	8
8	7½
9	7
10	6½
11	6
12	5½
13	5
14	4½
15	4
16	3½
17	3
18	2½

It will readily be seen that each pair of treads and risers thus obtained is suitably proportioned as to dimensions.

It is seldom, however, that the proportions of treads and risers are entirely a matter of choice. The space allotted to the stairs usually determines this proportion; but the above will be found a useful standard, to which it is desirable to approximate.

In the better class of buildings, the number of steps is considered in the plan, which it is the business of the Architect to arrange; and in such cases, the height of the story rod is simply divided into the number required.

Pitch-Board. It will now be in order to describe a pitch-board and the manner of using it; no stairs can be properly built without the use of a pitch-board in some form or other. Properly speaking, a pitch-board, as already explained, is a thin piece of material, generally pine or sheet metal, and is a right-angled triangle in outline. One of its sides is made the exact height of the rise; at right angles with this line of rise, the exact width of the tread is measured off; and the material is cut along the hypotenuse of the right-angled triangle thus formed.

The simplest method of making a pitch-board is by using a steel

square, which, of course, every carpenter in this country is supposed to possess. By means of this invaluable tool, also, a stair string can be laid out, the square being applied to the string as shown in Fig. 13.

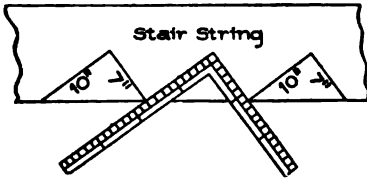


Fig. 13. Steel Square Used as a Pitch-Board in Laying Out Stair String.

In the instance here illustrated, the square shows 10 inches for the tread and 7 inches for the rise.

To cut a pitch-board, after the tread and rise have been determined, proceed as follows: Take a piece of thin, clear material, and lay the square on the face edge, as shown in Fig. 13. Mark out the

pitch-board with a sharp knife; then cut out with a fine saw, and dress to the knife marks; nail a piece on the largest edge of the pitch-board for a gauge or fence, and it is ready for use.

Fig. 14 shows the pitch-board pure and simple; it may be half an inch thick, or, if of hardwood, may be from a quarter-inch to a half-inch thick.

Fig. 15 shows the pitch-board after the gauge or fence is nailed on. This fence or gauge may be about $1\frac{1}{2}$ inches wide and from $\frac{3}{8}$ to $\frac{1}{4}$ inch thick.

Fig. 16 shows a sectional view of the pitch-board with a fence nailed on.

In Fig. 17 the manner of applying the pitch-board is shown. *RRR* is the string, and the line *A* shows the jointed or straight edge of the string. The pitch-board *P* is shown in position, the line $8\frac{1}{2}$ represents the step or tread, and the line $7\frac{1}{4}$ shows the line of the riser. These two lines are of course



Fig. 14.

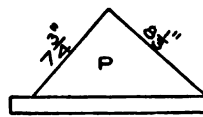


Fig. 15.

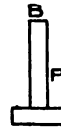


Fig. 16.

Showing How a Pitch-Board is Made.
Fig. 15 shows gauge fastened to long edge; Fig. 16 is a sectional elevation of completed board.

at right angles, or, as the carpenter would say, they are *square*. This string shows four complete cuts, and part of a fifth cut for treads, and five complete cuts for risers. The bottom of the string at *W* is cut off at the line of the floor on which it is supposed to rest. The line *C* is the line of the first riser. This riser is cut lower

Housed strings are those which carry the treads and risers without their ends being seen. In an open stair, the wall string only is housed, the other ends of the treads and risers resting on a cut string, and the nosings and mouldings being returned as before described.

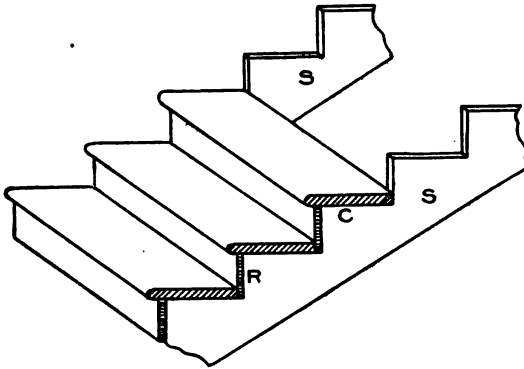


Fig. 18. Portion of Stair in Position.

good glue before insertion in the groove. The housings are generally made from $\frac{1}{2}$ to $\frac{3}{8}$ inch deep, space for the wedge being cut to suit.

In some closed stairs in which there is a housed string between the newels, the string is double-tenoned into the shanks of both newels, as shown in Fig. 20. The string in this example is made $12\frac{1}{2}$ inches wide, which is a very good width for a string of this kind; but the thickness should never be less than $1\frac{1}{2}$ inches. The upper newel is made about 5 feet 4 inches long from drop to top of cap. These strings are generally capped with a subrail of some kind, on which the baluster, if any, is cut-mitered in. Generally a groove, the width of the square of the balusters, is worked on the top of the subrail, and the balusters are worked out to fit into this groove; then pieces of this material, made the width of the groove and a little thicker than the groove is deep, are cut so as to fit in snugly between the ends of the balusters resting in the groove. This makes a solid job; and the pieces between the balusters may be made

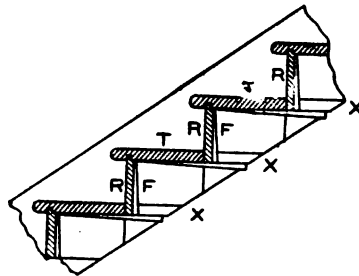
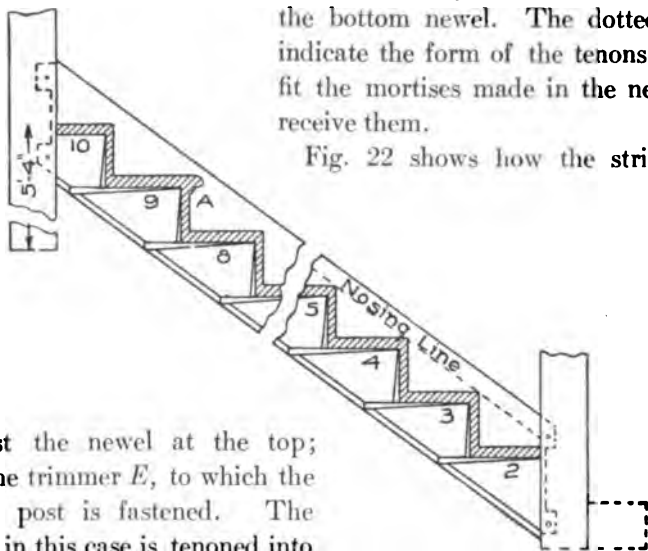


Fig. 19. Showing Method of Housing Treads and Risers.

of any shape on top, either beveled, rounded, or moulded, in which case much is added to the appearance of the stairs.

Fig. 21 exhibits the method of attaching the rail and string to the bottom newel. The dotted lines indicate the form of the tenons cut to fit the mortises made in the newel to receive them.



against the newel at the top; also the trimmer *E*, to which the newel post is fastened. The string in this case is tenoned into the upper newel post the same way as into the lower one.

Fig. 22 shows how the string fits

Fig. 20. Showing Method of Connecting Housed String to Newels.

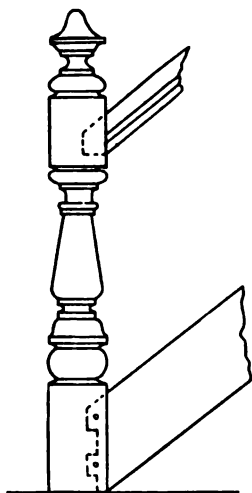


Fig. 21. Method of Connecting Rail and String to Bottom Newel.

The open string shown in Fig. 23 is a portion of a finished string, showing nosings and cove returned and finishing against the face of the string. Along the lower edge of the string is shown a bead or moulding, where the plaster is finished.

A portion of a stair of the better class is shown in Fig. 24. This is an open, bracketed string, with returned nosings and coves and scroll brackets. These brackets are made about $\frac{3}{8}$ inch thick, and may be in any desirable pattern. The end next the riser should be mitered to suit; this will require the riser to be $\frac{3}{8}$ inch longer than the face of the string. The upper part of the bracket should run under the cove moulding; and the tread should project over the string the full $\frac{3}{8}$ inch, so as to cover the

bracket and make the face even for the nosing and the cove moulding to fit snugly against the end of the tread and the face of the bracket. Great care must be taken about this point, or endless trouble will

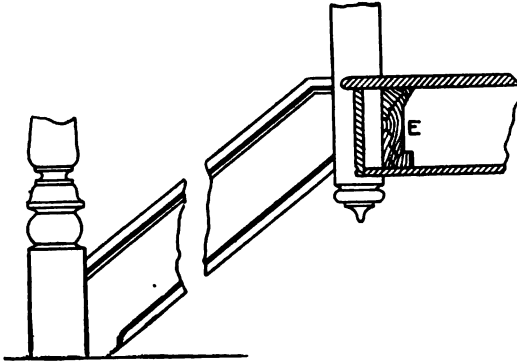


Fig. 22. Connections of String and Trimmer at Upper Newel Post.

follow. In a bracketed stair of this kind, care must be taken in placing the newel posts, and provision must be made for the extra $\frac{3}{8}$ inch due to the bracket. The newel post must be set out from the string $\frac{3}{8}$ inch, and it will then align with the baluster.

We have now described several methods of dealing with strings; but there are still a few other points connected with these members, both housed and open, that it will be necessary to explain, before the young workman can proceed to build a fair flight of stairs. The connection of the wall string to the lower and upper floors, and the manner of affixing the outer or cut string to the upper joist and to the newel,

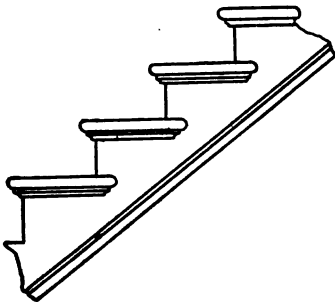


Fig. 23. Portion of Finished String, Showing Returned Nosings and Cove, also Bead Moulding.

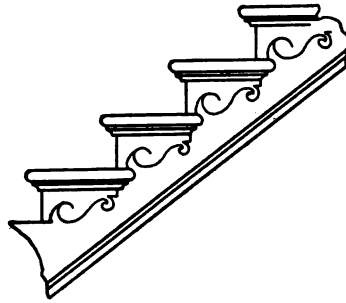


Fig. 24. Portion of Open, Bracketed String Stair, with Returned Nosings and Cove, Scroll Brackets, and Bead Moulding.

are matters that must not be overlooked. It is the intention to show how these things are accomplished, and how the stairs are made strong by the addition of rough strings or bearing carriages.

Fig. 25 gives a side view of part of a stair of the better class, with one open, cut and mitered string. In Fig. 26, a plan of this same stairway, *W S* shows the wall string; *R S*, the rough string, placed there

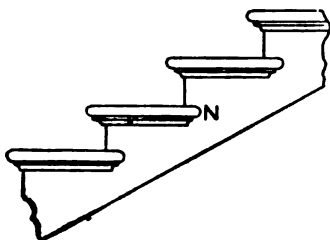


Fig. 25. Side Elevation of Part of Stair with Open, Cut and Mitered String.

to give the structure strength; and *O S*, the outer or cut and mitered string. At *A A* the ends of the risers are shown, and it will be noticed that they are mitered against a vertical or riser line of the string, thus preventing the end of the riser from being seen. The other end of the riser is in the housing in the wall string. The outer end of the tread is also mitered at the nosing, and a piece of material made or worked like the

nosing is mitered against or returned at the end of the tread. The end of this returned piece is again returned on itself back to the string, as shown at *N* in Fig. 25. The moulding, which is $\frac{3}{8}$ -inch cove in this case, is also returned on itself back to the string.

The mortises shown at *B B B B* (Fig. 26), are for the balusters. It is always the proper thing to saw the ends of the treads ready for the balusters before the treads are attached to the string; then, when the time arrives to put up the rail, the back ends of the mortises can be cut out, when the treads will be ready to receive the balusters. The mortises are dovetailed, and, of course, the tenons on the balusters must be made to suit. The treads are finished on the bench; and the return nosings are fitted to them and tacked on, so that they may be taken off to insert the balusters when the rail is being put in position.

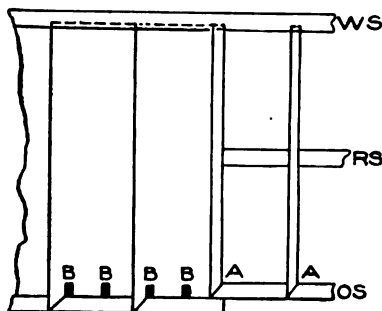


Fig. 26. Plan of Part of Stair Shown in Fig. 25.

Fig. 27 shows the manner in which a wall string is finished at the foot of the stairs. *S* shows the string, with moulding wrought on the upper edge. This moulding may be a simple ogee, or may consist of a number of members; or it may be only a bead; or, again, the edge of the string may be

left quite plain; this will be regulated in great measure by the style of finish in the hall or other part of the house in which the stairs are placed. *B* shows a portion of a baseboard, the top edge of which has the same finish as the top edge of the string. *B* and *A* together

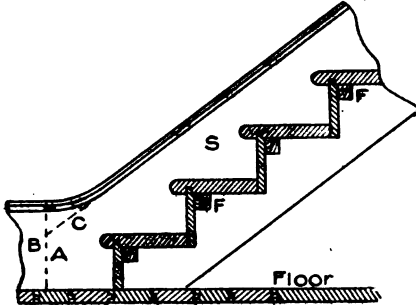


Fig. 27. Showing How Wall String is Finished at Foot of Stair.

show the junction of the string and base. *F F* show blocks glued in the angles of the steps to make them firm and solid.

Fig. 28 shows the manner in which the wall string *S* is finished at the top of the stairs. It will be noticed that the moulding is worked round the case-off at *A* to suit the width of the base at *B*. The string is cut to fit the floor and to

butt against the joist. The plaster line under the stairs and on the ceiling, is also shown.

Fig. 29 shows a cut or open string at the foot of a stairway, and the manner of dealing with it at its junction with the newel post *K*. The point of the string should be mortised into the newel 2 inches, 3 inches, or 4 inches, as shown by the dotted lines; and the mortise in the newel should be cut near the center, so that the center of the baluster will be directly opposite the central line of the newel post. The proper way to manage this, is to mark the central line of the baluster on the tread, and then make this line correspond with the central line of the newel post. By careful attention to this point, much trouble will be avoided where a turned cap is used to receive the lower part of the rail.

The lower riser in a stair of this kind will be somewhat shorter than the ones above it, as it must be cut to fit between the newel and

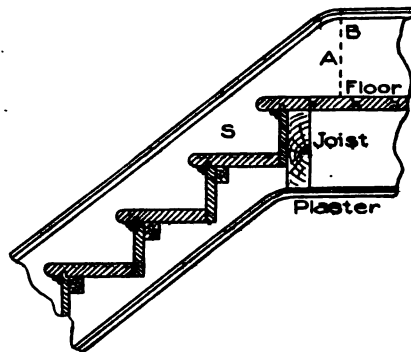


Fig. 28. Showing How Wall String is Finished at Top of Stair.

the wall string. A portion of the tread, as well as of the riser, will also butt against the newel, as shown at *W*.

If there is no spandrel or wall under the open string, it may run down to the floor as shown by the dotted line at *O*. The piece *O* is glued to the string, and the moulding is worked on the curve. If there is a wall under the string *S*, then the base *B*, shown by the dotted lines, will finish against the string, and it should have a moulding on its upper edge, the same as that on the lower edge of the string, if any, this moulding being mitered into the one on the string. When there is a base, the piece *O* is of course dispensed with.

The square of the newel should run down by the side of a joist as shown, and should be firmly secured to the joist either by spiking

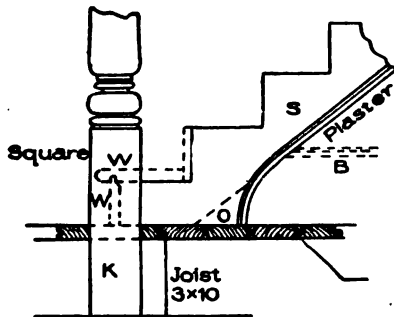


Fig. 29. Showing How a Cut or Open String is Finished at Foot of Stair.

or by some other suitable device. If the joist runs the other way, try to get the newel post against it, if possible, either by furring out the joist or by cutting a portion off the thickness of the newel. The solidity of a stair and the firmness of the rail, depend very much upon the rigidity of the newel post. The above suggestions are applicable where great

strength is required, as in public buildings. In ordinary work, the usual method is to let the newel rest on the floor.

Fig. 30 shows how the cut string is finished at the top of the stairs. This illustration requires no explanation after the instructions already given.

Thus far, stairs having a newel only at the bottom have been dealt with. There are, however, many modifications of straight and return stairs which have from two to four or six newels. In such cases, the methods of treating strings at their finishing points must necessarily be somewhat different from those described; but the general principles, as shown and explained, will still hold good.

Well-Hole. Before proceeding to describe and illustrate neweled stairs, it will be proper to say something about the *well-hole*, or the





RESIDENCE OF MR. W. H. KNIGHT, BRISTOL, R. I.
Parkhurst & Kissam, Architects
Built of Solid Reinforced Concrete. Plans Shown on Opposite Page



opening through the floors, through which the traveler on the stairs ascends or descends from one floor to another.

Fig. 31 shows a well-hole, and the manner of trimming it. In this instance the stairs are placed against the wall; but this is not necessary in all cases, as the well-hole may be placed in any part of the building.

The arrangement of the trimming varies according as the joists are at right angles to, or are parallel to, the wall against which the stairs are built. In the former case (Fig. 31, *A*) the joists are cut short and tusk-tenoned into the heavy trimmer *T T*, as shown in the cut. This trimmer is again tusk-tenoned into two heavy joists *T J* and *T J*, which form the ends of the well-hole. These heavy joists are called *trimming joists*; and, as they have to carry a much heavier load than other joists on the same floor, they are made much heavier. Sometimes two or three joists are placed together, side by side, being bolted or spiked together to give them the desired unity and strength. In constructions requiring great strength, the tail and header joists of a well-hole are suspended on iron brackets.

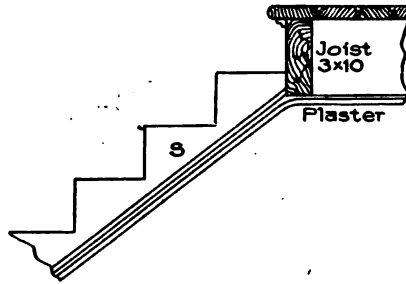


Fig. 30. Showing How a Cut or Open String is Finished at Top of Stair.

If the opening runs parallel with the joists (Fig. 31, *B*), the timber forming the side of the well-hole should be left a little heavier than the other joists, as it will have to carry short trimmers (*T J* and *T J*) and the joists running into them. The method here shown is more particularly adapted to brick buildings, but there is no reason why the same system may not be applied to frame buildings.

Usually in cheap, frame buildings, the trimmers *T T* are spiked against the ends of the joists, and the ends of the trimmers are supported by being spiked to the trimming joists *T J*, *T J*. This is not very workmanlike or very secure, and should not be done, as it is not nearly so strong or durable as the old method of framing the joists and trimmers together.

Fig. 32 shows a stair with three newels and a platform. In this

example, the first tread (No. 1) stands forward of the newel post two-thirds of its width. This is not necessary in every case, but it is sometimes done to suit conditions in the hallway. The second newel is placed at the twelfth riser, and supports the upper end of the first

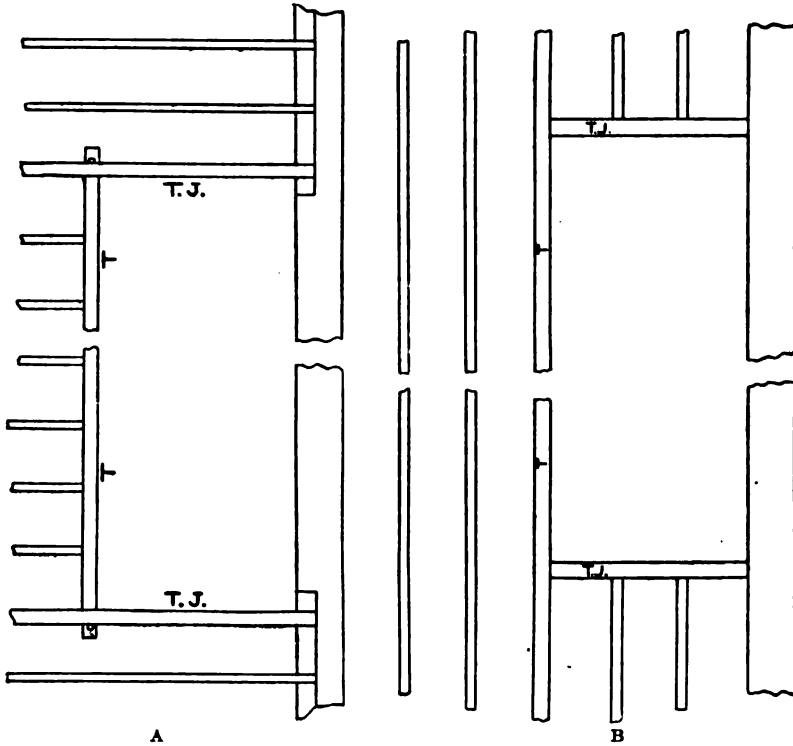


Fig. 31. Showing Ways of Trimming Well-Hole when Joists Run in Different Directions.

cut string and the lower end of the second cut string. The platform (12) is supported by joists which are framed into the wall and are fastened against a trimmer running from the wall to the newel along the line 12. This is the case only when the second newel runs down to the floor.

If the second newel does not run to the floor, the framework supporting the platform will need to be built on studding. The third newel stands at the top of the stairs, and is fastened to the joists of the second floor, or to the trimmer, somewhat after the manner of fastening shown in Fig. 29. In this example, the stairs have 16 risers

and 15 treads, the platform or landing (12) making one tread. The figure 16 shows the floor in the second story.

This style of stair will require a well-hole in shape about as shown in the plan; and where strength is required, the newel at the top should run from floor to floor, and act as a support to the joists and trimmers on which the second floor is laid.

Perhaps the best way for a beginner to go about building a stairway of this type, will be to lay out the work on the lower floor in the exact place where the stairs are to be erected, making everything

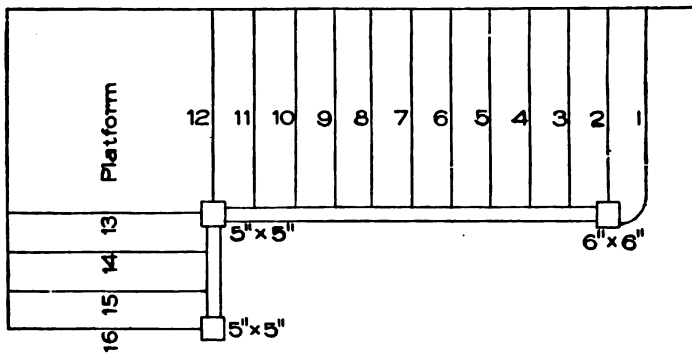


Fig. 32. Stair with Three Newels and a Platform.

full size. There will be no difficulty in doing this; and if the positions of the first riser and the three newel posts are accurately defined, the building of the stairs will be an easy matter. Plumb lines can be raised from the lines on the floor, and the positions of the platform and each riser thus easily determined. Not only is it best to line out on the floor all stairs having more than one newel; but in constructing any kind of stair it will perhaps be safest for a beginner to lay out in exact position on the floor the points over which the treads and risers will stand. By adopting this rule, and seeing that the strings, risers, and treads correspond exactly with the lines on the floor, many cases of annoyance will be avoided. Many expert stair-builders, in fact, adopt this method in their practice, laying out all stairs on the floor, including even the carriage strings, and they cut out all the material from the lines obtained on the floor. By following this method, one can see exactly the requirements in each particular case, and can rectify any error without destroying valuable material.

Laying Out. In order to afford the student a clear idea of what is meant by *laying out* on the floor, an example of a simple close-string stair is given. In Fig. 33, the letter *F* shows the floor line; *L* is the landing or platform; and *W* is the wall line. The stair is to be 4 feet wide over strings; the landing, 4 feet wide; the height from floor to landing, 7 feet; and the run from start to finish of the stair, 8 feet 8½ inches.

The first thing to determine is the dimensions of the treads and risers. The wider the tread, the lower must be the riser, as stated before. No definite dimensions for treads and risers can be given, as the steps have to be arranged to meet the various difficulties that may occur in the working out of the construction; but a common rule is this: Make the width of the tread, plus twice the rise, equal to 24 inches. This will give, for an 8-inch tread, an 8-inch rise; for a 9-inch tread, a 7½-inch rise; for a 10-inch tread, a 7-inch rise; and so on. Having the height (7 feet) and the run of the flight (8 feet 8½ inches), take a rod about one inch square, and mark on it the height from floor to landing (7 feet), and the length of the going or run of the flight (8 feet 8½ inches). Consider now what are the dimensions which can be given to the treads and risers, remembering that there will be one more riser than the number of treads. Mark off on the rod the landing, forming the last tread. If twelve risers are desired, divide the height (namely, 7 feet) by 12, which gives 7 inches as the rise of each step. Then divide the run (namely, 8 feet 8½ inches) by 11, and the width of the tread is found to be 9½ inches.

Great care must be taken in making the pitch-board for marking off the treads and risers on the string. The pitch-board may be made from dry hardwood about ¾ inch thick. One end and one side must be perfectly square to each other; on the one, the width of the tread is set off, and on the other the height of the riser. Connect the two points thus obtained, and saw the wood on this line. The addition of a gauge-piece along the longest side of the triangular piece, completes the pitch-board, as was illustrated in Fig. 15.

The length of the wall and outer string can be ascertained by means of the pitch-board. One side and one edge of the wall string must be squared; but the outer string must be trued all round. On the strings, mark the positions of the treads and risers by using the pitch-board as already explained (Fig. 17). Strings are usually

made 11 inches wide, but may be made $12\frac{1}{2}$ inches wide if necessary for strength.

After the widths of risers and treads have been determined, and the string is ready to lay out, apply the pitch-board, marking the

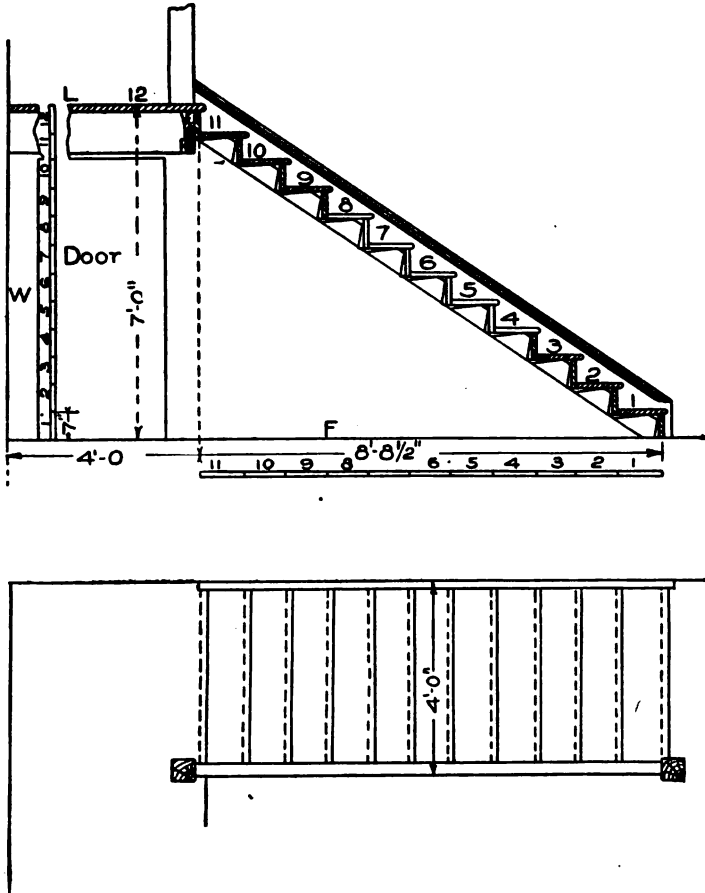


Fig. 33. Method of Laying Out a Simple, Close-String Stair.

first riser about 9 inches from the end; and number each step in succession. The thickness of the treads and risers can be drawn by using thin strips of hardwood made the width of the housing required. Now allow for the wedges under the treads and behind the risers, and thus find the exact width of the housing, which should be about $\frac{5}{8}$ inch

deep; the treads and risers will require to be made $1\frac{1}{2}$ inches longer than shown in the plan, to allow for the housings at both ends.

Before putting the stair together, be sure that it can be taken into the house and put in position without trouble. If for any reason it cannot be put in after being put together, then the parts must be assembled, wedged, and glued up at the spot.

It is essential in laying out a plan on the floor, that the exact positions of the first and last risers be ascertained, and the height of the story wherein the stair is to be placed. Then draw a plan of the hall or other room in which the stairs will be located, including surrounding or adjoining parts of the room to the extent of ten or twelve feet from the place assigned for the foot of the stair. All the doorways, branching passages, or windows which can possibly come in contact with the stair from its commencement to its expected termination or landing, must be noted. The sketch must necessarily include a portion of the entrance hall in one part, and of the lobby or landing in another, and on it must be laid out all the lines of the stair from the first to the last riser.

The height of the story must next be exactly determined and taken on the rod; then, assuming a height of risers suitable to the place, a trial is made by division in the manner previously explained, to ascertain how often this height is contained in the height of the story. The quotient, if there is no remainder, will be the number of risers required. Should there be a remainder on the first division, the operation is reversed, the number of inches in the height being made the dividend and the before-found quotient the divisor; and the operation of reduction by division is carried on till the height of the riser is obtained to the thirty-second part of an inch. These heights are then set off as exactly as possible on the story rod, as shown in Fig. 33.

The next operation is to show the risers on the sketch. This the workman will find no trouble in arranging, and no arbitrary rule can be given.

A part of the foregoing may appear to be repetition; but it is not, for it must be remembered that scarcely any two flights of stairs are alike in run, rise, or pitch, and any departure in any one dimension from these conditions leads to a new series of dimensions that must be dealt with independently. The principle laid down, however, applies to all straight flights of stairs; and the student who has followed

closely and retained the pith of what has been said, will, if he has a fair knowledge of the use of tools, be fairly equipped for laying out and constructing a plain, straight stair with a straight rail.

Plain stairs may have one platform, or several; and they may turn to the right or to the left, or, rising from a platform or landing, may run in an opposite direction from their starting point.

When two flights are necessary for a story, it is desirable that each flight should consist of the same number of steps; but this, of course, will depend on the form of the staircase, the situation and height of doors, and other obstacles to be passed under or over, as the case may be.

In Fig. 32, a stair is shown with a single platform or landing and three newels. The first part of this stair corresponds, in number of risers, with the stair shown in Fig. 33; the second newel runs down to the floor, and helps to sustain the landing. This newel may simply be a 4 by 4-inch post, or the whole space may be inclosed with the spandrel of the stair. The second flight starts from the platform just as the first flight starts from the lower floor, and both flights may be attached to the newels in the manner shown in Fig. 29. The bottom tread in Fig. 32 is rounded off against the square of the newel post; but this cannot well be if the stairs start from the landing, as the tread would project too far onto the platform. Sometimes, in high-class stairs, provision is made for the first tread to project well onto the landing.

If there are more platforms than one, the principles of construction will be the same; so that whenever the student grasps the full conditions governing the construction of a single-platform stair, he will be prepared to lay out and construct the body of any stair having one or more landings. The method of laying out, making, and setting up a hand-rail will be described later.

Stairs formed with treads each of equal width at both ends, are named *straight flights*; but stairs having treads wider at one end than the other are known by various names, as *winding stairs*, *dog-legged stairs*, *circular stairs*, or *elliptical stairs*. A tread with parallel sides, having the same width at each end, is called a *flyer*; while one having one wide end and one narrow, is called a *winder*. These terms will often be made use of in what follows.

The elevation and plan of the stair shown in Fig. 34 may be called a *dog-legged* stair with three winders and six flyers. The flyers, however, may be extended to any number. The housed strings to receive the winders are shown. These strings show exactly the manner of construction. The shorter string, in the corner from 1 to 4, which is shown in the plan to contain the housing of the first winder and

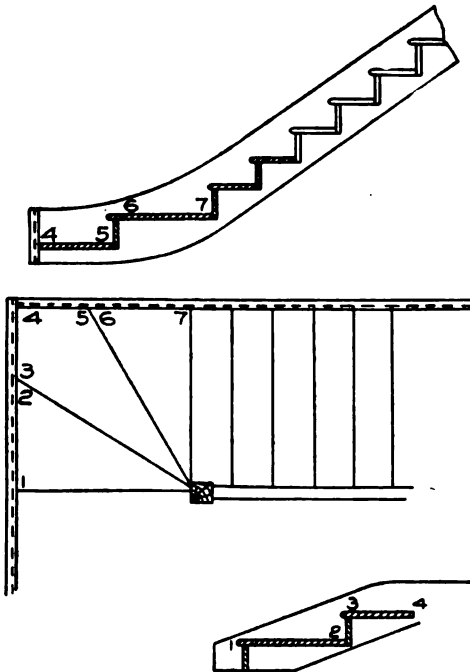


Fig. 34. Elevation and Plan of Dog-Legged Stair with Three Winders and Six Flyers.

half of the second, is put up first, the treads being leveled by aid of a spirit level; and the longer upper string is put in place afterwards, butting snugly against the lower string in the corner. It is then fastened firmly to the wall. The winders are cut snugly around the newel post, and well nailed. Their risers will stand one above another on the post; and the straight string above the winders will enter the post on a line with the top edge of the uppermost winder.

Platform stairs are often constructed so that one flight will run in a direction opposite to that of the

other flight, as shown in Fig. 35. In cases of this kind, the landing or platform requires to have a length more than double that of the treads, in order that both flights may have the same width. Sometimes, however, and for various reasons, the upper flight is made a little narrower than the lower; but this expedient should be avoided whenever possible, as its adoption unbalances the stairs. In the example before us, eleven treads, not including the landing, run in one direction; while four treads, including the landing, run in the opposite direction; or, as workmen put it, the stair "returns on itself." The elevation

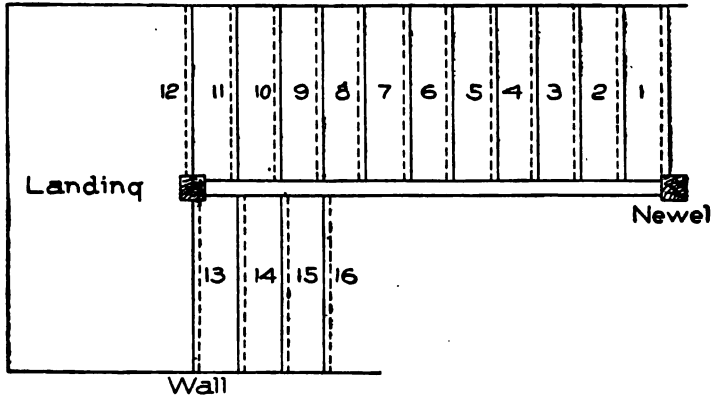


Fig. 85. Plan of Platform Stair Returning on Itself.

shown in Fig. 36 illustrates the manner in which the work is executed. The various parts are shown as follows:

Fig. 37 is a section of the top landing, with baluster and rail.

Fig. 38 is part of the long newel, showing mortises for the strings.

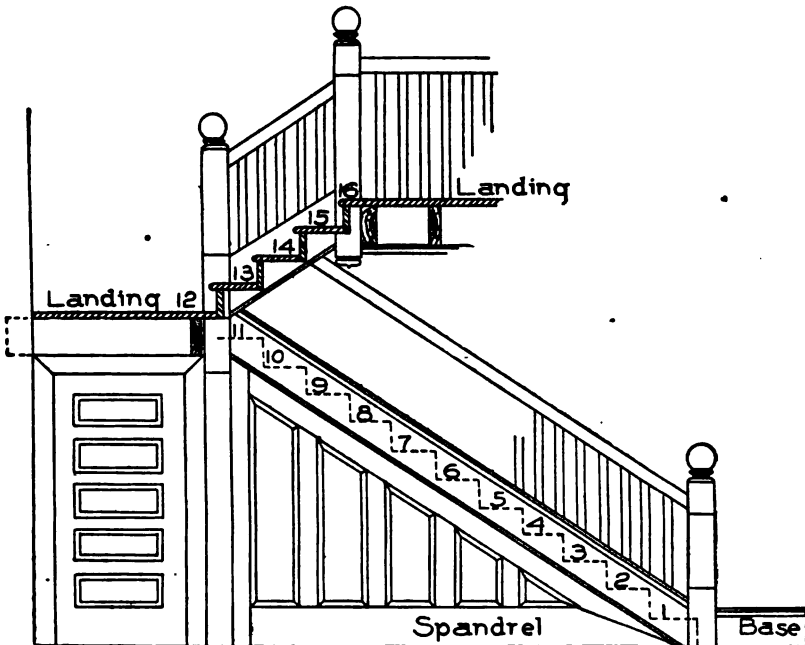


Fig. 86. Elevation Showing Construction of Platform Stair of which Plan is Given in Fig. 85.

Fig. 39 represents part of the bottom newel, showing the string, moulding on the outside, and cap.

Fig. 40 is a section of the top string enlarged.

Fig. 41 is the newel at the bottom, as cut out to receive bottom step. It must be remembered that there is a *cove* under each tread. This may be nailed in after the stairs are put together, and it adds greatly to the appearance.

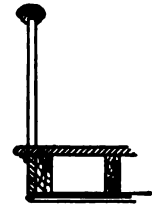


Fig. 37. Section of Top Landing, Baluster, and Rail.

We may state that stairs should have *carriage pieces* fixed from floor to floor, under the stairs, to support them. These may be notched under the steps; or *rough brackets* may be nailed to the side of the carriage, and carried under each riser and tread.

There is also a framed spandrel which helps materially to carry the weight, makes a sound job, and adds greatly to the appearance. This spandrel may be made of 1½-inch material, with panels and mouldings on the front side, as shown in Fig. 36. The joint between the top and bottom rails of the spandrel at the angle, should be made as shown in Fig. 42 with a cross-tongue, and glued and fastened with long screws. Fig. 43 is simply one of the panels showing the miters on the moulding and the shape of the sections. As there is a convenient space under the landing, it is commonly used for a closet.



Fig. 38. String Mortises in Long Newel.



Fig. 39. Mortises in Lower Newel for String, Outside Moulding, and Cap.

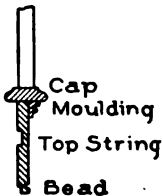


Fig. 40. Enlarged Section of Top String.

In setting out stairs, not only the proportions of treads and risers must be considered, but also the material available. As this material runs, as a rule, in certain sizes, it is best to work so as to conform to it as nearly as possible. In ordinary stairs, 11 by 1-inch common stock is used for strings and treads, and 7-inch by ¾-inch stock for risers; in stairs of a better class, wider and thicker material may be used. The rails are set at various heights; 2 feet 8 inches may be

taken as an average height on the stairs, and 3 feet 1 inch on landings, with two balusters to each step.

In Fig. 36, all the newels and balusters are shown square; but it is much better, and is the more common practice, to have them

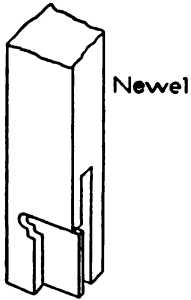


Fig. 41. Newel Cut to Receive Bottom Step.

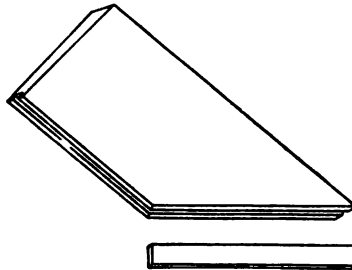


Fig. 42. Showing Method of Joining Spandrel Rails, with Cross-Tongue Glued and Screwed.

turned, as this gives the stairs a much more artistic appearance. The spandrel under the string of the stairway shows a style in which many stairs are finished in hallways and other similar places. Plaster is sometimes used instead of the panel work, but is not nearly so good as woodwork. The door under the landing may open into a closet, or may lead to a cellarway, or through to some other room.

In stairs with winders, the width of a winder should, if possible, be nearly the width of the regular tread, at a distance of 14 inches from the narrow end, so that the length of the step in walking up or down the stairs may not be interrupted; and for this reason and several others, it is always best to have three winders only in each quarter-turn. Above all, avoid a four-winder turn, as this makes a breakneck stair, which is more difficult to construct and inconvenient to use.

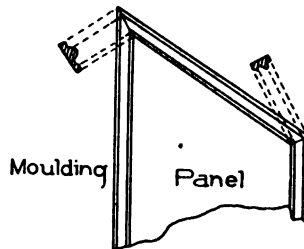
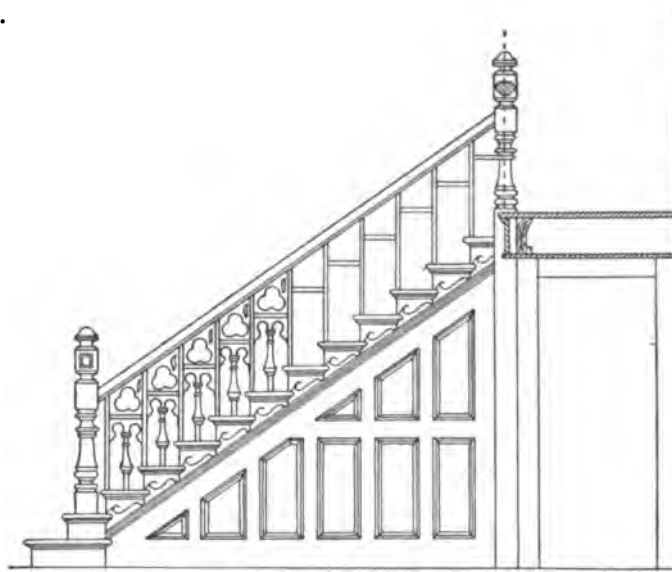


Fig. 43. Panel in Spandrel, Showing Mitters on Moulding, and Shape of Section.

Bullnose Tread. No other stair, perhaps, looks so well at the starting point as one having a *bullnose* step. In Fig. 44 are shown a plan and elevation of a flight of stairs having a bullnose tread. The method of obtaining the lines and setting out the body of the stairs,

is the same as has already been explained for other stairs, with the exception of the first two steps, which are made with circular ends, as shown in the plan. These circular ends are worked out as hereafter described, and are attached to the newel and string as shown.



Scale of  Feet

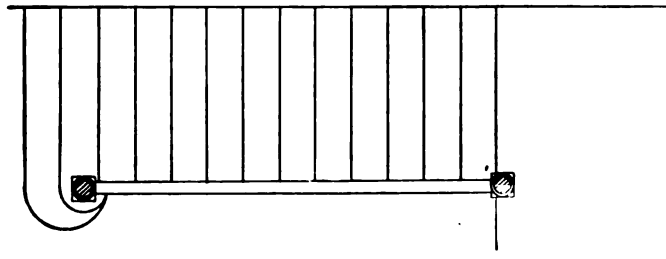


Fig. 44. Elevation and Plan of Stair with Bullnose Tread.

The example shows an open, cut string with brackets. The spandrel under the string contains short panels, and makes a very handsome finish. The newels and balusters in this case are turned, and the latter have cutwork panels between them.

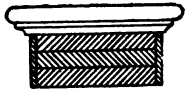


Fig. 45. Section through Bullnose Step.

Bullnose steps are usually built up with a three-piece block, as shown in Fig. 45, which is a section through the step indicating the blocks, tread, and riser.

Fig. 46 is a plan showing how the veneer of the riser is prepared before being bent into position. The block *A* indicates a wedge which is glued and driven home after the veneer is put in place. This tightens up the work and makes it sound and clear. Figs. 47 and 48 show other methods of forming bullnose steps.

Fig. 49 is the side elevation of an open-string stair with bullnose steps at the bottom; while Fig. 50 is a view showing the lower end of the string, and the manner in which it is prepared for fixing to the blocks of the step. Fig. 51 is a section through the string, showing the bracket, cove, and projection of tread over same.

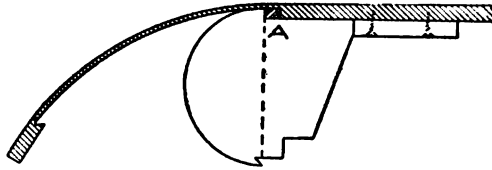


Fig. 46. Plan Showing Preparation of Veneer before Bending into Position.

Fig. 52 is a section through the string, showing the bracket, cove, and projection of tread over same.

Figs. 52 and 53 show respectively a plan and vertical section of the bottom part of the stair. The blocks are shown at the ends of the steps (Fig. 53), with the veneered parts of the risers going round them; also the position where the string is fixed to the blocks (Fig. 52); and

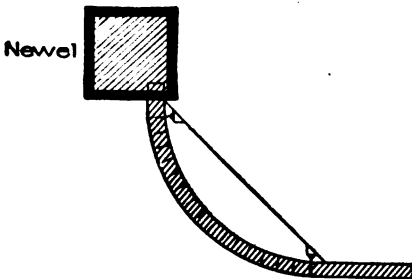


Fig. 47.

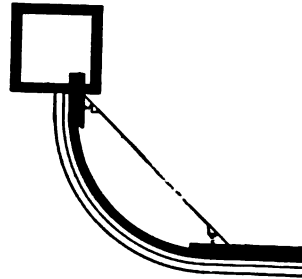


Fig. 48.

Methods of Forming Bullnose Steps.

the tenon of the newel is marked on the upper step. The section (Fig. 53) shows the manner in which the blocks are built up and the newel tenoned into them.

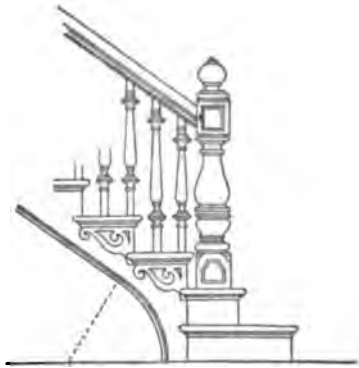


Fig. 49. Side Elevation of Open-String Stair with Bullnose Steps.

The newel, Fig. 49, is rather an elaborate affair, being carved at the base and on the body, and having a carved rosette planted in a small, sunken panel on three sides, the rail butting against the fourth side.

Open-Newel Stairs. Before leaving the subject of straight and dog-legged stairs, the student should be made familiar with at least one example of an open-newel stair. As the same principles of construction govern all styles of open-newel

stairs, a single example will be sufficient. The student must, of course, understand that he himself is the greatest factor in planning stairs of this type; that the setting out and designing will generally devolve on him. By exercising a little thought and foresight, he can so arrange his plan that a minimum of both labor and material will be required.

Fig. 54 shows a plan of an open-newel stair having two landings and closed strings, shown in elevation in Fig. 55. The dotted lines show the carriage timbers and trimmers, also the lines of risers; while the treads are shown by full lines. It will be noticed that the strings and trimmers at the first landing are framed into the shank of the second newel post, which runs down to the floor; while the top newel drops below

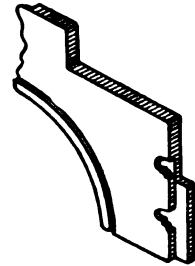


Fig. 50. Lower End of String to Connect with Bullnose Step.

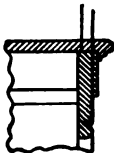


Fig. 51. Section through String.

the fascia, and has a turned and carved drop. This drop hangs below both the fascia and the string. The lines of treads and risers are shown by dotted lines and crosshatched sections. The position of the carriage timbers is shown both in the landings and in the runs of the stairs, the projecting ends of these timbers being supposed to be resting on the wall. A scale of the plan and elevation is attached to the plan. In Fig. 55, a story rod is shown at the right, with the number of risers spaced off thereon. The design of the newels, spandrel, framing, and paneling is shown.

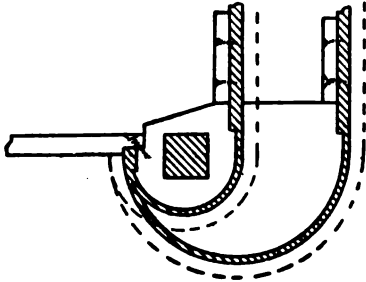


Fig. 52. Plan of Bottom Part of Bullnose Stair

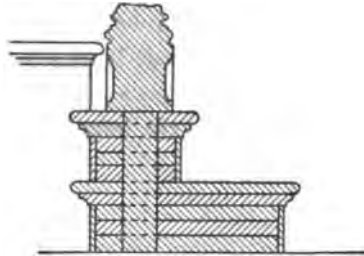


Fig. 53. Vertical Section through Bottom Part of Bullnose Stair.

Only the central carriage timbers are shown in Fig. 54; but in a stair of this width, there ought to be two other timbers, not so heavy, perhaps, as the central one, yet strong enough to be of service in lending additional strength to the stairway, and also to help carry the laths and plaster or the paneling which may be necessary in completing the under side or soffit. The strings being closed, the butts of their balusters must rest on a subrail which caps the upper edge of the outer string.

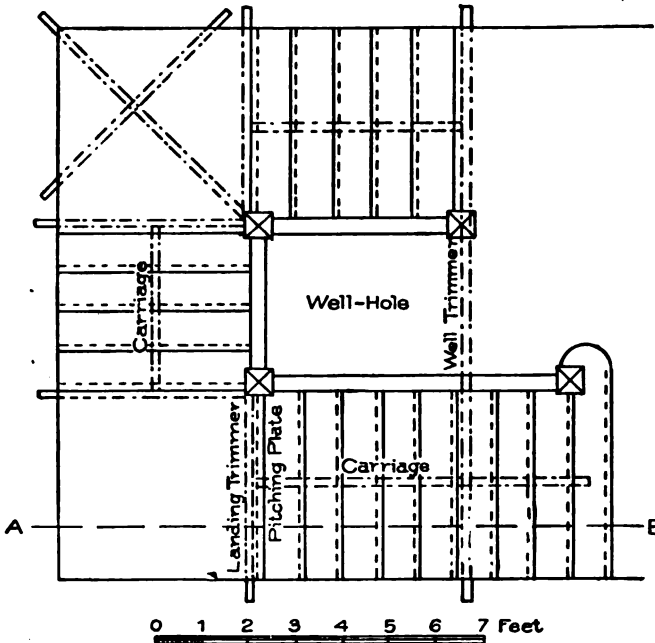


Fig. 54. Plan of Open-Newel Stair, with Two Landings and Closed Strings

The first newel should pass through the lower floor, and, to insure solidity, should be secured by bolts to a joist, as shown in the elevation. The rail is attached to the newels in the usual manner, with handrail bolts or other suitable device. The upper newel should be made fast to the joists as shown, either by bolts or in some other

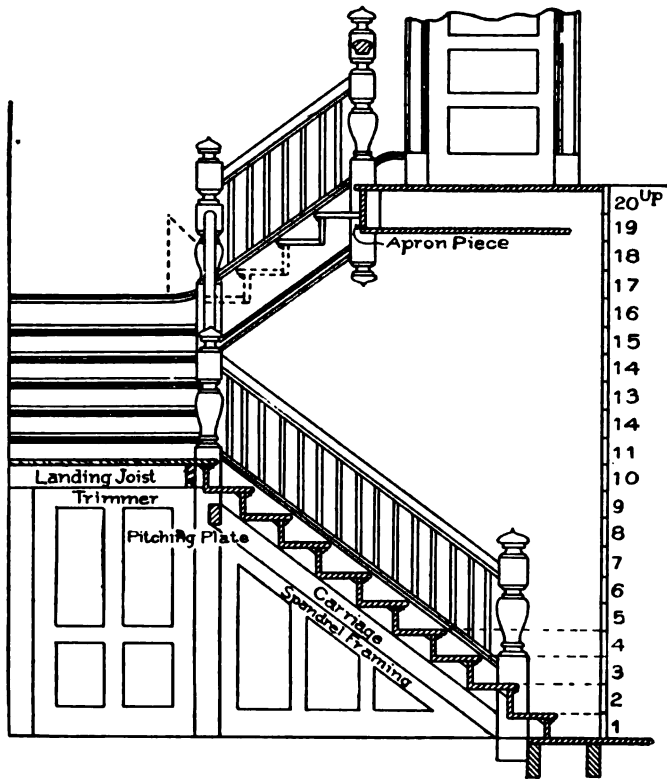


Fig. 55. Elevation of Open-Newel Stair Shown in Plan in Fig. 54.

efficient manner. The intermediate newels are left square on the shank below the stairs, and may be fastened in the floor below either by mortise and tenon or by making use of joint bolts.

Everything about a stair should be made solid and sound; and every joint should set firmly and closely; or a shaky, rickety, squeaky stair will be the result, which is an abomination.

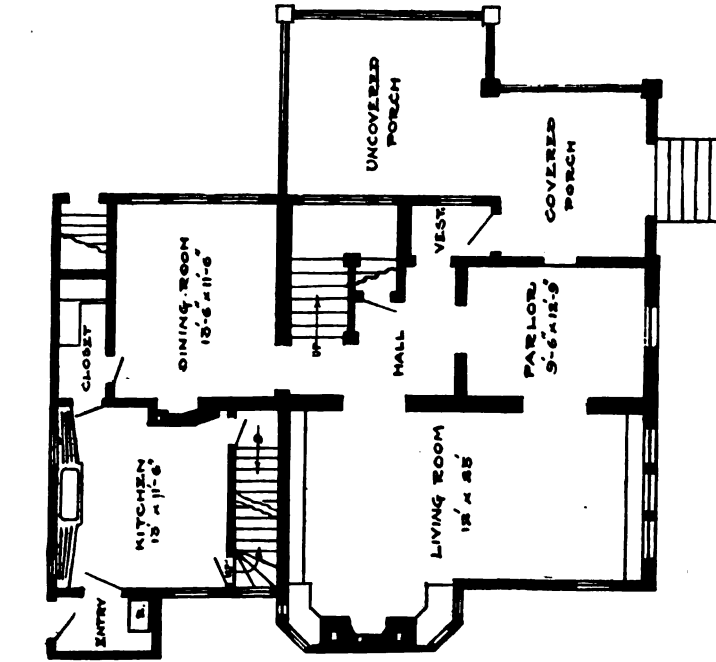
Stairs with Curved Turns. Sufficient examples of stairs having angles of greater or less degree at the turn or change of direction, to



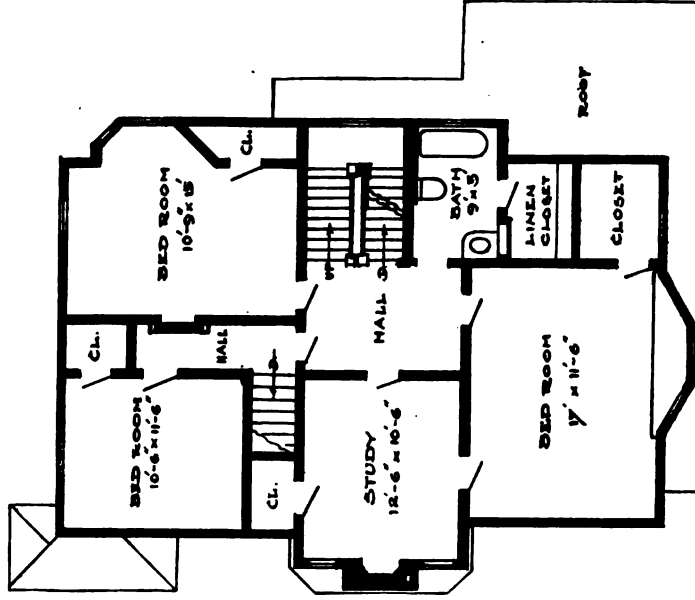


**EXTERIOR VIEW AND COMBINED LIBRARY AND LIVING ROOM IN HOUSE
AT URBANA, ILL.**

White & Temple, Architects, University of Illinois.
Plans Shown on Opposite Page.



FIRST FLOOR PLAN



SECOND FLOOR PLAN

FIRST AND SECOND FLOOR PLANS OF HOUSE IN URBANA, ILL
 White & Temple, Architects, University of Illinois.
 For Exterior and Interior Views See Opposite Page.



enable the student to build any stair of this class, have now been given. There are, however, other types of stairs in common use, whose turns are curved, and in which newels are employed only at the foot, and sometimes at the finish of the flight. These curved turns may be any part of a circle, according to the requirements of the case, but turns of a quarter-circle or half-circle are the more common. The string forming the curve is called a *cylinder*, or part of a cylinder, as the case may be. The radius of this circle or cylinder may be any length, according to the space assigned for the stair. The opening around which the stair winds is called the *well-hole*.

Fig. 56 shows a portion of a stairway having a well-hole with a 7-inch radius. This stair is rather peculiar, as it shows a quarter-space landing, and a quarter-space having three winders. The reason for this is the fact that the landing is on a level with the floor of another room, into which a door opens from the landing. This is a problem very often met with in practical work, where the main stair is often made to do the work of two flights because of one floor being so much lower than another.

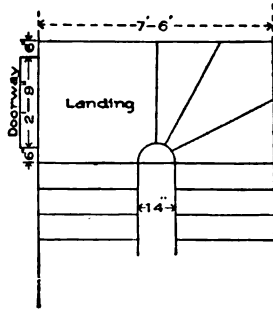


Fig. 56. Stair Serving for Two Flights, with Mid-Floor Landing.

A curved stair, sometimes called a *geometrical stair*, is shown in Fig. 57, containing seven winders in the cylinder or well-hole, the first and last aligning with the diameter.

In Fig. 58 is shown another example of this kind of stair, containing nine winders in the well-hole, with a circular wall-string. It is not often that stairs are built in this fashion, as most stairs having a circular well-hole finish against the wall in a manner similar to that shown in Fig. 57.

Sometimes, however, the workman will be confronted with a plan such as shown in Fig. 58; and he should know how to lay out the wall-string. In the elevation, Fig. 58, the string is shown to be straight, similar to the string of a common straight flight. This results from having an equal width in the winders along the wall-string, and, as we have of necessity an equal width in the risers, the development of the string is merely a straight piece of board, as in an ordinary straight flight. In laying out the string, all we have to do is to make

a common pitch-board, and, with it as a templet, mark the lines of the treads and risers on a straight piece of board, as shown at 1, 2, 3, 4, etc.

If you can manage to bend the string without kerfing (grooving), it will be all the better; if not, the kerfs (grooves) must be parallel to the rise. You can set out with a straight edge, full size, on a rough platform, just as shown in the diagram; and when the string is bent and set in place, the risers and winders will have their correct positions.

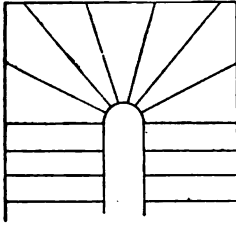


Fig. 57. Geometrical Stair with Seven Winders.

To bend these strings or otherwise prepare them for fastening against the wall, perhaps the easiest way is to saw the string with a fine saw, across the face, making parallel grooves. This method of bending is called *kerfing*, above referred to. The kerfs or grooves must be cut parallel to the lines of the risers, so as to be vertical when the string is in place. This method, however—handy though it may be—is not a good one, inasmuch as the saw groove will show more or less in the finished work.

Another method is to build up or *stave* the string. There are

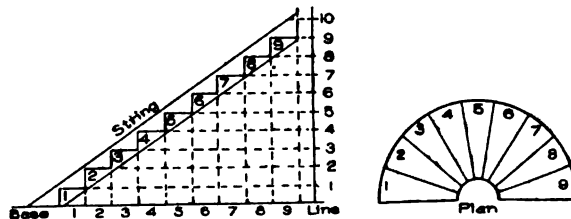


Fig. 58. Plan of Circular Stair and Layout of Wall String for Same.

several ways of doing this. In one, comparatively narrow pieces are cut to the required curve or to portions of it, and are fastened together, edge to edge, with glue and screws, until the necessary width is obtained (see Fig. 59). The heading joints may be either butted or beveled, the latter being stronger, and should be cross-tongued.

Fig. 60 shows a method that may be followed when a wide string is required, or a piece curved in the direction of its width is needed

for any purpose. The pieces are stepped over each other to suit the desired curve; and though shown square-edged in the figure, they are usually cut beveled, as then, by reversing them, two may be cut out of a batten.

Panels and quick sweeps for similar purposes are obtained in the manner shown in Fig. 61, by joining up narrow boards edge to edge

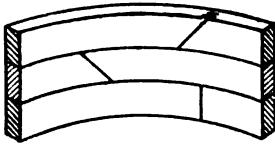


Fig. 59.

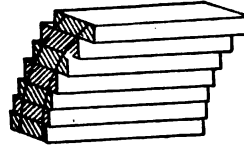


Fig. 60.

Methods of Building Up Strings.

at a suitable level to give the desired curve. The internal curve is frequently worked approximately, before gluing up. The numerous joints incidental to these methods limit their uses to painted or unimportant work.

In Fig. 62 is shown a wreath-piece or curved portion of the outside string rising around the cylinder at the half-space. This is formed by reducing a short piece of string to a veneer between the springings; bending it upon a cylinder made to fit the plan; then, when it is secured in position, filling up the back of the veneer with staves glued across it; and, finally, gluing a piece of canvas over the whole. The appearance of the wreath-piece after it has been built up and removed from the cylinder is indicated in Fig. 63. The canvas back has been omitted to show the staving; and the counter-wedge key used for connecting the wreath-piece with the string is shown. The wreath-piece is, at this stage, ready for marking the outlines of the steps.

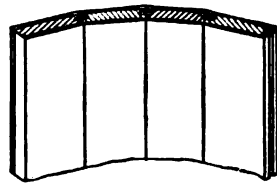


Fig. 61. Building Up a Curved Panel or Quick Sweep.

Fig. 62 also shows the drum or shape around which strings may be bent, whether the strings are formed of veneers, staved, or kerfed. Another drum or shape is shown in Fig. 64. In this, a portion of a cylinder is formed in the manner clearly indicated; and the string, being set out on a veneer board sufficiently thin to bend easily, is laid

down round the curve, such a number of pieces of like thickness being then added as will make the required thickness of the string. In working this method, glue is introduced between the veneers, which



Fig. 62. Wreath-Piece Bent around Cylinder.

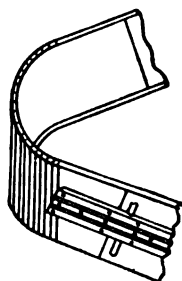


Fig. 63. Completed Wreath-Piece Removed from Cylinder.

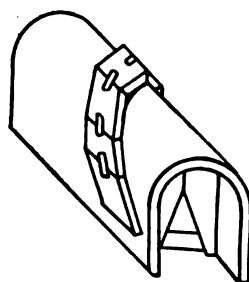


Fig. 64. Another Drum or Shape for Building Curved Strings.

are then quickly strained down to the curved piece with hand screws. A string of almost any length can be formed in this way, by gluing a few feet at a time, and when that dries, removing the cylindrical curve and gluing down more, until the whole is completed. Several other methods will suggest themselves to the workman, of building up good, solid, circular strings.

One method of laying out the treads and risers around a cylinder or drum, is shown in Fig. 65. The line *D* shows the curve of the rail. The lines showing treads and risers may be marked off on the cylinder, or they may be marked off after the veneer is bent around the drum or cylinder.

There are various methods of making inside cylinders or wells, and of fastening same to strings. One method is shown in Fig. 66. This gives a strong joint when properly made. It will be noticed that the cylinder is notched out on the back; the two blocks shown at the back of the offsets are wedges driven in to secure the cylinder in place, and to drive it up tight to the strings. Fig. 67 shows an 8-inch well-hole with cylinder complete; also the method of trimming and finishing same. The cylinder, too, is shown in such a manner that its construction will be readily understood.

Stairs having a cylindrical or circular opening always require a weight support underneath them. This support, which is generally made of rough lumber, is called the *carriage*, because it is supposed

to carry any reasonable load that may be placed upon the stairway. Fig. 68 shows the under side of a half-space stair having a carriage beneath it. The timbers marked *S* are of rough stuff, and may be 2-inch by 6-inch or of greater dimensions. If they are cut to fit the risers and treads, they will require to be at least 2-inch by 8-inch.

In preparing the rough carriage for the winders, it will be best to let the back edge of the tread project beyond the back of the riser so that it forms a ledge as shown under *C* in Fig. 69. Then fix the cross-carriage pieces under the winders, with the back edge about flush with the backs of risers, securing one end to the well with screws, and the other to the wall string or the wall. Now cut short pieces, marked *O O* (Fig. 68), and fix them tightly in between the cross-carriage and the back of the riser as at *B B* in the section, Fig. 69. These carriages should be of 3-inch by 2-inch material. Now get a piece of wood, 1-inch by 3-inch, and cut pieces *C C* to fit tightly between the top back edge of the winders (or the ledge) and the pieces marked *B B* in section. This method makes a very sound and strong job of the winders; and if the stuff is roughly planed, and blocks are glued on each side of the short cross-pieces *O O O*, it is next to impossible for the winders ever to spring or squeak. When the weight is carried in this manner, the plasterer will

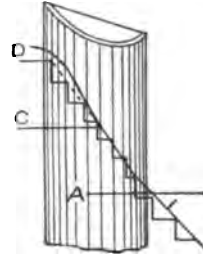


Fig. 65. Laying Out Treads and Risers around a Drum.

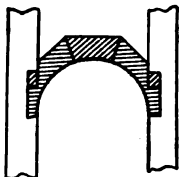


Fig. 66. One Method of Making an Inside Well.

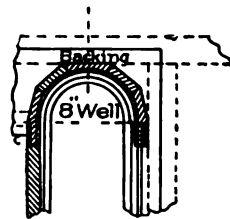


Fig. 67. Construction and Trimming of 8-Inch Well-Hole.

have very little trouble in lathing so that a graceful soffit will be made under the stairs.

The manner of placing the main stringers of the carriage *S S*, is shown at *A*, Fig. 69. Fig. 68 shows a complete half-space stair:

one-half of this, finished as shown, will answer well for a quarter-space stair.

Another method of forming a carriage for a stair is shown in Fig. 70. This is a peculiar but very handsome stair, inasmuch as the first and the last four steps are parallel, but the remainder *balance* or *dance*. The treads are numbered in this illustration; and the plan of

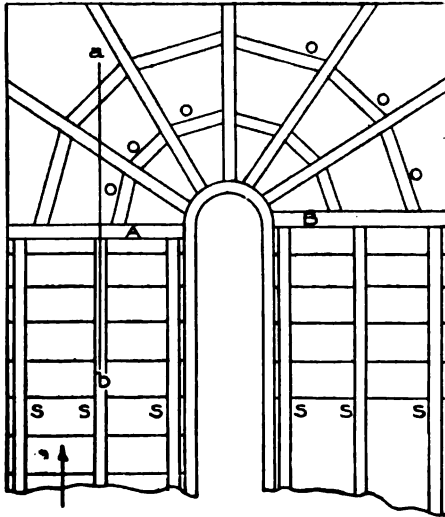


Fig. 68. Under Side of Half-Space Stair, with Carriages and Cross-Carriages.

the handrail is shown extending from the scroll at the bottom of the stairs to the landing on the second story. The trimmer *T* at the top of the stairs is also shown; and the rough strings or carriages, *R S, R S, R S*, are represented by dotted lines.

This plan represents a stair with a curtail step, and a scroll handrail resting over the curve of the curtail step. This type of stair is not now much in vogue in this country, though it is adopted occa-

sionally in some of the larger cities. The use of heavy newel posts instead of curtail steps, is the prevailing style at present.

In laying out geometrical stairs, the steps are arranged on principles already described. The well-hole in the center is first laid down and the steps arranged around it. In circular stairs with an open well-hole, the handrail being on the inner side, the width of tread for the steps should be set off at about 18 inches from the handrail, this giving an approximately uniform rate of progress for anyone ascending or descending the stairway. In stairs with the rail on the outside, as sometimes occurs, it will be sufficient if the treads have the proper width at the middle point of their length.

Where a flight of stairs will likely be subject to great stress and wear, the carriages should be made much heavier than indicated in

the foregoing figures; and there may be cases when it will be necessary to use iron bolts in the sides of the rough strings in order to give them greater strength. This necessity, however, will arise only in the case

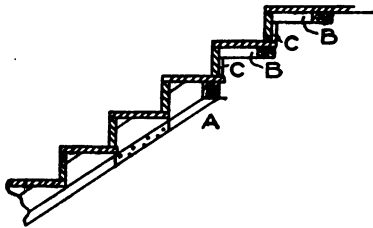


Fig. 69. Method of Reinforcing Stair.

of stairs built in public buildings, churches, halls, factories, warehouses, or other buildings of a similar kind. Sometimes, even in house stairs, it may be wise to strengthen the treads and risers by spiking pieces of board to the rough string, ends up, fitting them snugly against the under side of the tread and the

back of the riser. The method of doing this is shown in Fig. 71, in which the letter *O* shows the pieces nailed to the string.

Types of Stairs in Common Use. In order to make the student familiar with types of stairs in general use at the present day, plans of a few of those most likely to be met with will now be given.

Fig. 72 is a plan of a straight stair, with an ordinary cylinder at the top provided for a return rail on the landing. It also shows a stretch-out stringer at the starting.

Fig. 73 is a plan of a stair with a landing and return steps.

Fig. 74 is a plan of a stair with an acute angular landing and cylinder.

Fig. 75 illustrates the same kind of stair as Fig. 74, the angle, however, being obtuse.

Fig. 76 exhibits a stair having a half-turn with two risers on landings.

Fig. 77 is a plan of a quarter-space stair with four winders.

Fig. 78 shows a stair similar to Fig. 77, but with six winders.

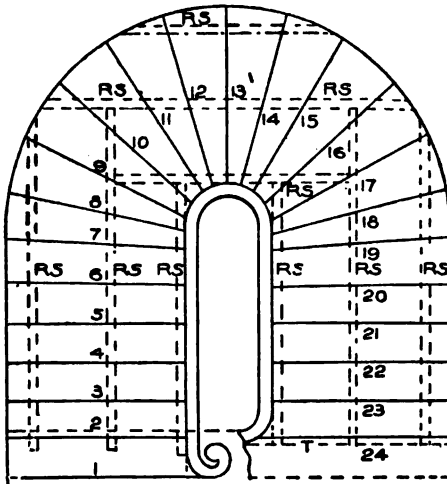


Fig. 70. Plan Showing One Method of Constructing Carriage and Trimming Winding Stair.

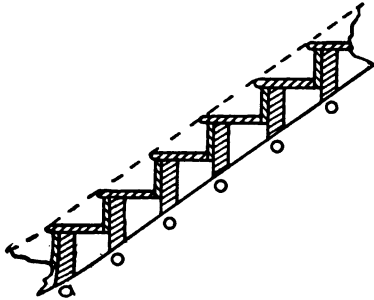


Fig. 71. Reinforcing Treads and Risers by Blocks Nailed to String.

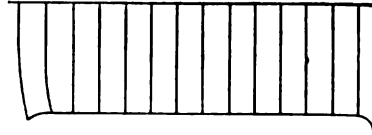


Fig. 72. Plan of Straight Stair with Cylinder at Top for Return Rail.

Fig. 79 shows a stair having five dancing winders.

Fig. 80 is a plan of a half-space stair having five dancing winders and a quarter-space landing.

Fig. 81 shows a half-space stair with dancing winders all around the cylinder.

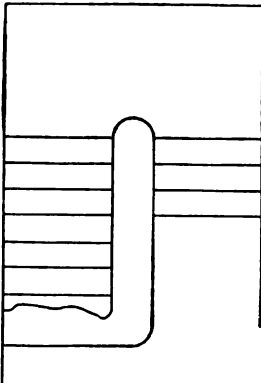


Fig. 73. Plan of Stair with Landing and Return Steps.

Fig. 82 shows a geometrical stair having winders all around the cylinder.

Fig. 83 shows the plan and elevation of stairs which turn around a central post. This kind of stair is frequently used in large stores and in clubhouses and other similar places, and has a very graceful appearance. It is not very difficult to build if properly planned.

The only form of stair not shown which the student may be called upon to build, would very likely be one having an elliptical plan; but, as this form is so seldom used—being found, in fact, only in public buildings or great mansions—it rarely falls to the lot of the ordinary workman to be called upon to design or construct a stairway of this type.

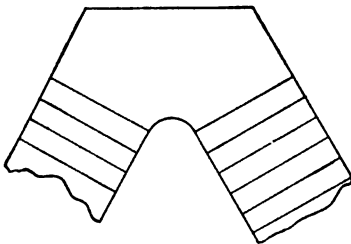


Fig. 74. Plan of Stair with Acute-Angle Landing and Cylinder.

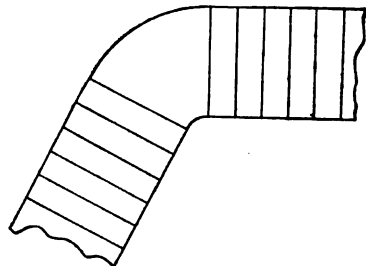


Fig. 75. Plan of Stair with Obtuse-Angle Landing and Cylinder.

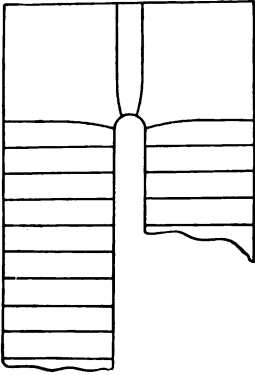


Fig. 76. Half-Turn Stair with Two Risers on Landings.

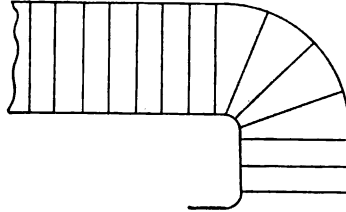


Fig. 77. Quarter-Space Stair with Four Winders.

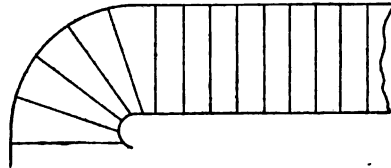


Fig. 79. Stair with Five Dancing Winders.

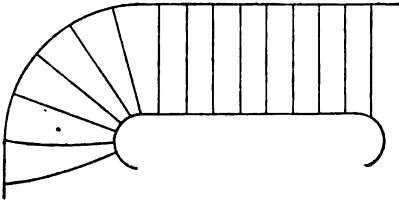


Fig. 78. Quarter-Space Stair with Six Winders.

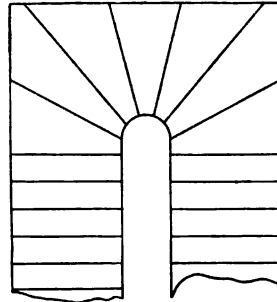


Fig. 81. Half-Space Stair with Dancing Winders all around Cylinder.

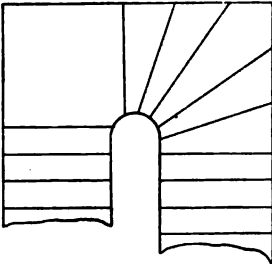


Fig. 80. Half-Space Stair with Five Dancing Winders and Quarter-Space Landing.

GEOMETRICAL STAIRWAYS AND HANDRAILING

The term *geometrical* is applied to stairways having any kind of curve for a plan.

The rails over the steps are made continuous from one story to another. The resulting winding or twisting pieces are called *wreaths*.

Wreaths. The construction of wreaths is based on a few geometrical problems—namely, the projection of straight and curved lines into an oblique plane; and the finding of the angle of inclination of the plane into which the lines and curves are projected. This angle

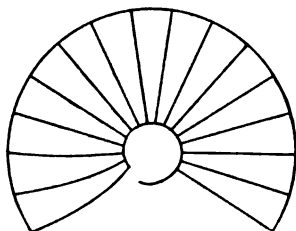


Fig. 82. Geometrical Stair with Winders all Around Cylinder.

is called the *bevel*, and by its use the wreath is made to twist.

In Fig. 84 is shown an obtuse-angle plan; in Fig. 85, an acute-angle plan; and in Fig. 86, a semicircle enclosed within straight lines.

Projection. A knowledge of how to project the lines and curves in each of these plans into an oblique plane, and to find the angle of inclination of the plane, will enable the student to construct any and all kinds of wreaths.

The straight lines *a, b, c, d* in the plan, Fig. 86, are known as *tangents*; and the curve, the *central line* of the plan wreath.

The straight line across from *n* to *n* is the *diameter*; and the perpendicular line from it to the lines *c* and *b* is the *radius*.

A *tangent* line may be defined as a line touching a curve without cutting it, and is made use of in handrailing to square the joints of the wreaths.

Tangent System. The *tangent system* of handrailing takes its name from the use made of the tangents for this purpose.

In Fig. 86, it is shown that the joints connecting the central line of rail with the plan rails *w* of the straight flights, are placed right at the springing; that is, they are in line with the diameter of the semicircle, and square to the side tangents *a* and *d*.

The center joint of the crown tangents is shown to be square to tangents *b* and *c*. When these lines are projected into an oblique plane, the joints of the wreaths can be made to butt square by applying the bevel to them.

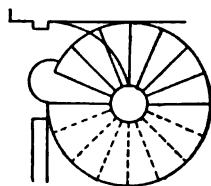


Fig. 83. Plan and Elevation of Stairs Turning around a Central Post.

All handrail wreaths are assumed to rest on an oblique plane while ascending around a well-hole, either in connecting two flights or in connecting one flight to a landing, as the case may be.

In the simplest cases of construction, the wreath rests on an inclined plane that inclines in one direction only, to either side of the well-hole; while in other cases it rests on a plane that inclines to two sides.

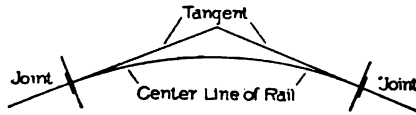


Fig. 84. Obtuse-Angle Plan.

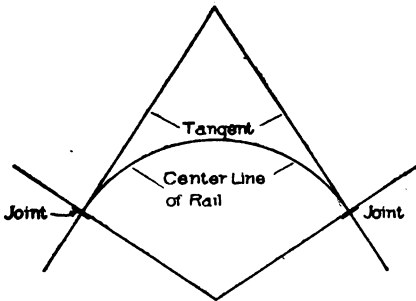


Fig. 85. Acute-Angle Plan.

Fig. 87 illustrates what is meant by a plane inclining in one direction. It will be noticed that the lower part of the figure is a reproduction of the quadrant enclosed by the tangents *a* and *b* in Fig. 86. The quadrant, Fig. 87, represents a central line of a wreath that is to ascend from the joint on the plan tangent *a* the height of *h* above the tangent *b*.

In Fig. 88, a view of Fig. 87 is given in which the tangents *a* and *b* are shown in plan, and also the quadrant representing the plan central line of a wreath. The curved line extending from *a* to *h* in this figure represents the development of the central line of the plan wreath, and, as shown, it rests on an oblique plane inclining to one side only—namely, to the side of the plan tangent *a*. The joints are made square to the developed tangents *a* and *m* of the inclined plane; it is for this purpose only that tangents are made use of in wreath construction. They are shown in the figure to consist of two lines, *a* and *m*, which are two adjoining sides of a developed section (in

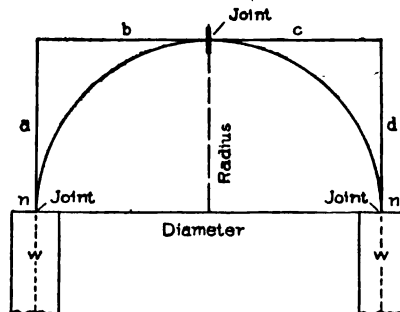
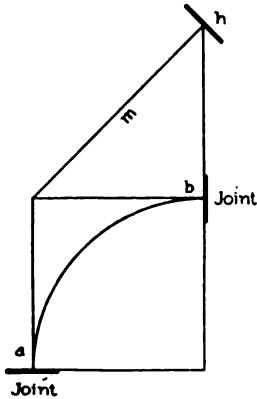


Fig. 86. Semicircular Plan.

this case, of a square prism), the section being the assumed inclined plane whereon the wreath rests in its ascent from *a* to *h*. The joint at *h*, if made square to the tangent *m*, will be a true, square butt-joint; so also will be the joint at *a*, if made square to the tangent *a*.



Joint
Fig. 87. Illustrating Plane Inclined in One Direction Only.

In practical work it will be required to find the correct geometrical angle between the two developed tangents *a* and *m*; and here, again, it may be observed that the finding of the correct angle between the two developed tangents is the essential purpose of every tangent system of handrailing.

In Fig. 89 is shown the geometrical solution—the one necessary to find the angle between the tangents as required on the face-mould to square the joints of the wreath. The figure is shown to be similar to Fig. 87, except that it has an additional portion

marked "Section." This section is the true shape of the oblique plane whereon the wreath ascends, a view of which is given in Fig. 88. It will be observed that one side of it is the developed tangent *m*; another side, the developed tangent *a''* ($= a$). The angle between the two as here presented is the one required on the face-mould to square the joints.

In this example, Fig. 89, owing to the plane being oblique in one direction only, the shape of the section is found by merely drawing the tangent *a''* at right angles to the tangent *m*, making it equal in length to the level tangent *a* in the plan. By drawing lines parallel to *a''* and *m* respectively, the form of the section will be found, its outlines being the projections of the plan lines; and the angle between the two tangents, as already said, is the angle required on the face-mould to square the joints of the wreath.

The solution here presented will enable the student to find the

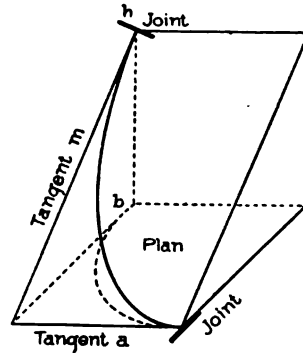


Fig. 88. Plan Line of Rail Projected into Oblique Plane Inclined to One Side Only.

correct direction of the tangents as required on the face-mould to square joints, in all cases of practical work where one tangent of a wreath is level and the other tangent is inclined, a condition usually met with in level-landing stairways.

Fig. 90 exhibits a condition of tangents where the two are equally inclined. The plan here also is taken from Fig. 86. The inclination of the tangents is made equal to the inclination of tangent *b* in Fig. 86, as shown at *m* in Figs. 87, 88, and 89.

In Fig. 91, a view of Fig. 90 is given, showing clearly the inclination of the tangents *c''* and *d''* over and above the plan tangents *c* and *d*. The central line of the wreath is shown extending along the sectional plane, over and above its plan lines, from one joint to the other, and, at the joints, made square to the inclined tangents *c''* and *d''*. It is evident from the view here given, that the condition necessary to square the joint at each end would be to find the true angle between the tangents *c''* and *d''*, which would give the correct direction to each tangent.

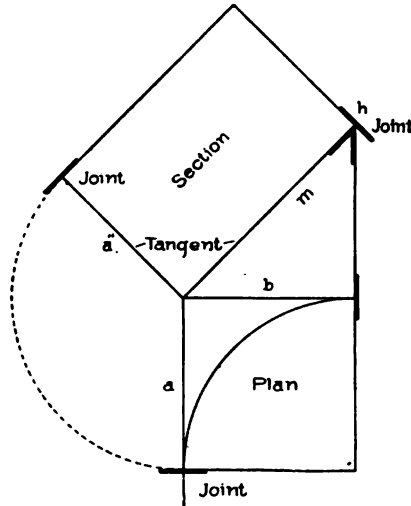


Fig. 89. Finding Angle between Tangents.

In Fig. 92 is shown how to find this angle correctly as required on the face-mould to square the joints. In this figure is shown the same plan as in Figs. 90 and 91, and the same inclination to the tangents as in Fig. 90, so that, except for the portion marked "Section," it would be similar to Fig. 90.

To find the correct angle for the tangents of the face-mould, draw the line *m* from *d*, square to the inclined line of the tangents *c' d'*; revolve the bottom inclined tangent *c'* to cut line *m* in *n*, where the joint is shown fixed; and from this point draw the line *c''* to *w*. The intersection of this line with the upper tangent *d''* forms the correct angle as required on the face-mould. By drawing the joints square to these two lines, they will butt square with the rail that is to connect

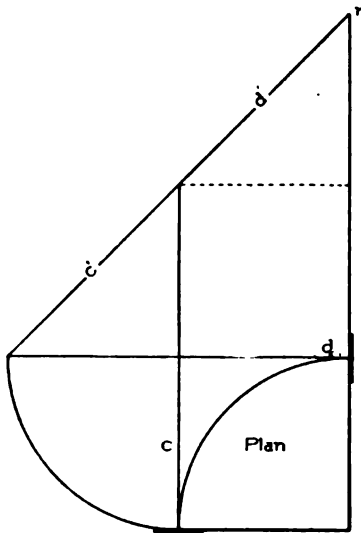


Fig. 90. Two Tangents Equally Inclined.

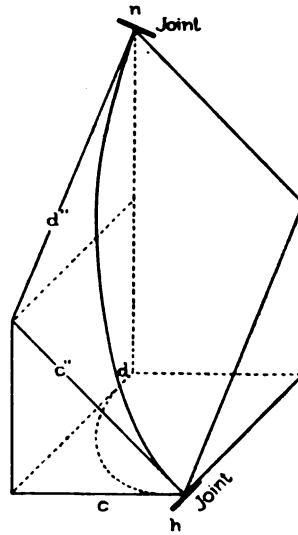


Fig. 91. Plan Lines Projected into Oblique Plane Inclined to Two Sides.

with them, or to the joint of another wreath that may belong to the cylinder or well-hole.

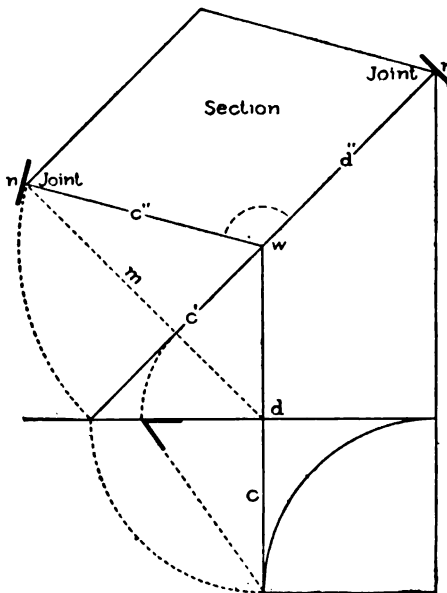


Fig. 92. Finding Angle between Tangents.

Fig. 93 is another view of these tangents in position placed over and above the plan tangents of the well-hole. It will be observed that this figure is made up of Figs. 88 and 91 combined. Fig. 88, as here presented, is shown to connect with a level-landing rail at *a*. The joint having been made square to the level tangent, *a* will butt square to a square end of the level rail. The joint at *h* is shown to connect the two wreaths and is made square to the inclined tan-

gent m of the lower wreath, and also square to the inclined tangent c'' of the upper wreath; the two tangents, aligning, guarantee a square butt-joint. The upper joint is made square to the tangent d'' , which is here shown to align with the rail of the connecting flight; the joint will consequently butt square to the end of the rail of the flight above.

The view given in this diagram is that of a wreath starting from a level landing, and winding around a well-hole, connecting the landing with a flight of stairs leading to a second story. It is presented to elucidate the use made of tangents to square the joints in wreath construction. The wreath is shown to be in two sections, one extending from the level-landing rail at a to a joint in the center of the well-hole at h , this section having one level tangent a and one inclined tangent m ; the other section is shown to extend from h to n , where it is butt-jointed to the rail of the flight above.

This figure clearly shows that the joint at a of the bottom wreath—owing to the tangent a being level and therefore aligning with the level rail of the landing—will be a true butt-joint; and that the joint at h , which connects the two wreaths, will also be a true butt-joint, owing to it being made square to

the tangent m of the bottom wreath and to the tangent c'' of the upper wreath, both tangents having the same inclination; also the joint at n will butt square to the rail of the flight above,

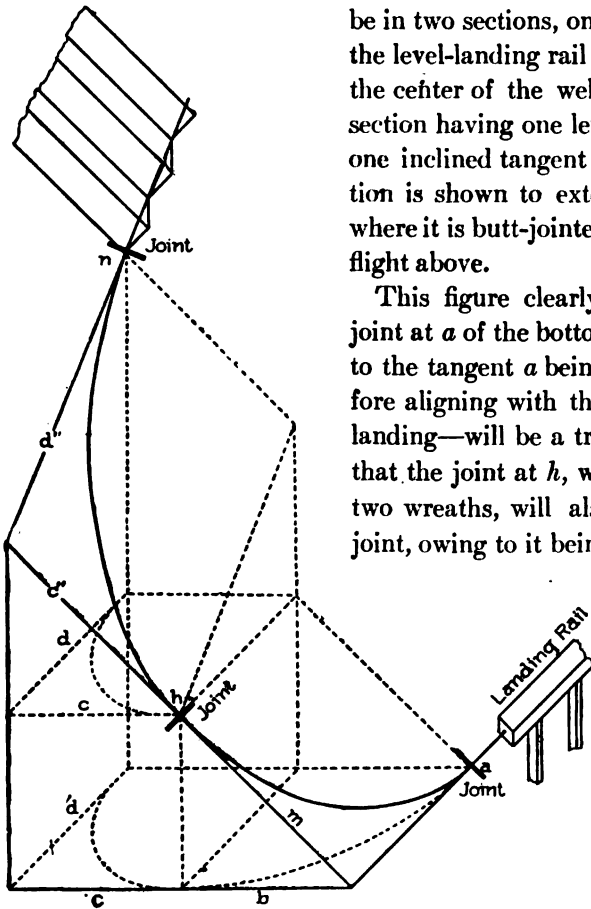


Fig. 93. Laying Out Line of Wreath to Start from Level-Landing Rail, Wind around Well-Hole, and Connect at Landing with Flight to Upper Story.

owing to it being made square to the tangent d'' , which is shown to have the same inclination as the rail of the flight adjoining.

As previously stated, the use made of tangents is to square the joints of the wreaths; and in this diagram it is clearly shown that the way they can be made of use is by giving each tangent its true direction. How to find the true direction, or the angle between the tangents

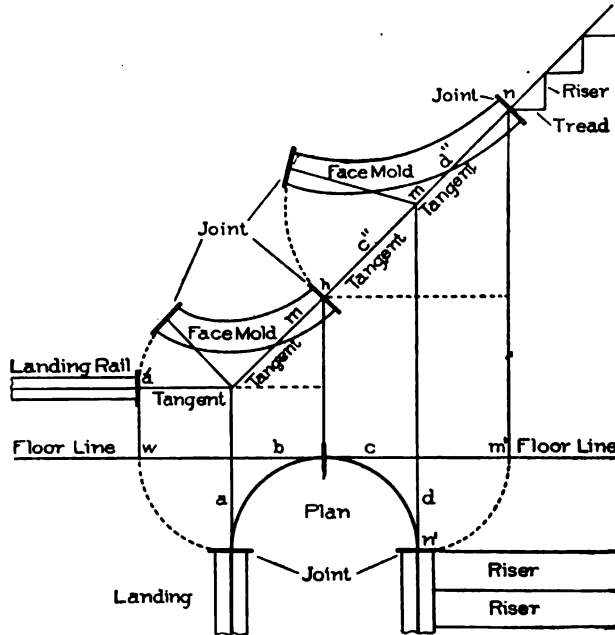


Fig. 94. Tangents Unfolded to Find Their Inclination.

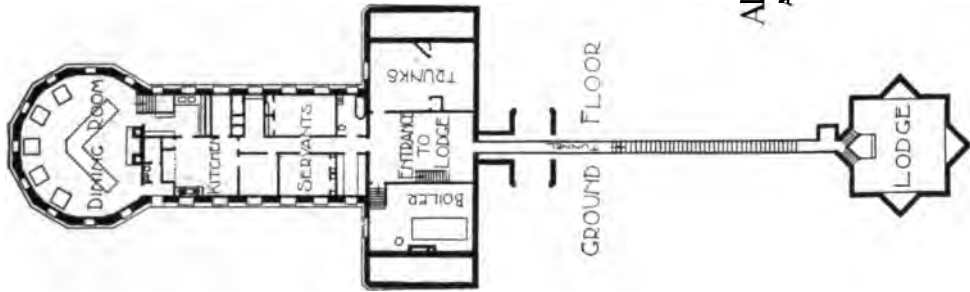
a and m shown in this diagram, was demonstrated in Fig. 89; and how to find the direction of the tangents c'' and d'' was shown in Fig. 92.

Fig. 94 is presented to help further toward an understanding of the tangents. In this diagram they are unfolded; that is, they are stretched out for the purpose of finding the inclination of each one over and above the plan tangents. The side plan tangent a is shown stretched out to the floor line, and its elevation a' is a level line. The side plan tangent d is also stretched out to the floor line, as shown by the arc $n'm'$. By this process the plan tangents are now in one straight line on the floor line, as shown from w to m' . Upon each one, erect a perpendicular line as shown, and from m' measure to n , the height the wreath is to ascend around the well-hole. In

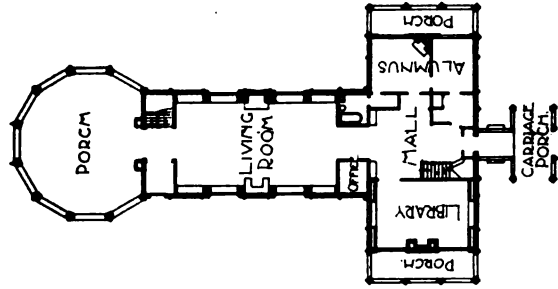




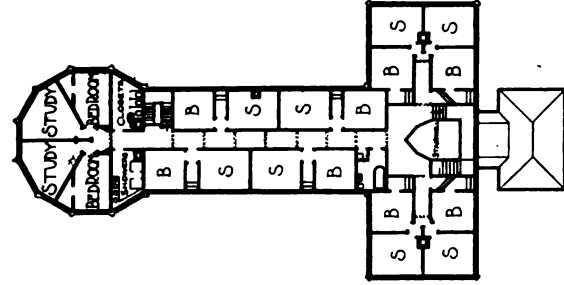
ALPHA DELTA PHI CHAPTER-HOUSE AT CORNELL UNIVERSITY, ITHACA, N. Y.
Dean & Dean, Architects, Chicago, Ill.



GROUND FLOOR



FIRST FLOOR



SECOND FLOOR

ALPHA DELTA PHI HOUSE
AT CORNELL UNIVERSITY, ITHACA.
GEORGE B. DEAN ARCHITECT
216 LA SALLE STREET CHICAGO

PLANS OF ALPHA DELTA PHI CHAPTER-HOUSE AT CORNELL UNIVERSITY, ITHACA, N. Y.
Dean & Dean, Architects, Chicago, Ill.
Interior Shown on Opposite Page.



practice, the number of risers in the well-hole will determine this height.

[illegible]

c'' and *d''*, coincides with the pitch-line of the same tangents as presented in Fig. 92, where they are used to find the true angle between the tangents as it is required on the face-mould to square the joints of the wreath at *h*.

In Fig. 89 the same pitch is shown given to tangent m as in Fig. 94; and in both figures the pitch is shown to be the same as that over and above the upper connecting tangents c'' and d'' , which is a necessary condition where a joint, as shown at h in Figs. 93 and 94, is to connect two pieces of wreath as in this example.

In Fig. 94 are shown the two face-moulds for the wreaths, placed

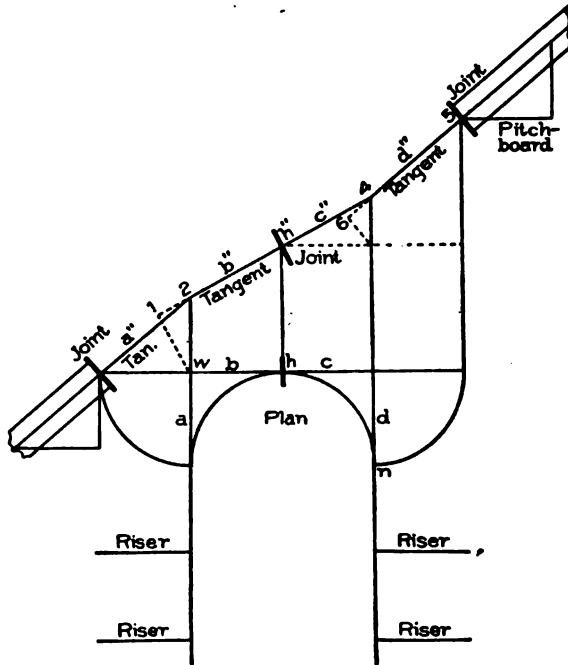


Fig. 95. Well-Hole Connecting Two Flights, with Two Wreath-Pieces, Each Containing Portions of Unequal Pitch.

upon the pitch-line of the tangents over the well-hole. The angles between the tangents of the face-moulds have been found in this figure by the same method as in Figs. 89 and 92, which, if compared with the present figure, will be found to correspond, excepting only the curves of the face-moulds in Fig. 94.

The foregoing explanation of the tangents will give the student a fairly good idea of the use made of tangents in wreath construction. The treatment, however, would not be complete if left off at this point, as it shows how to handle tangents under only two conditions—namely, first, when one tangent inclines and the other is level, as at *a* and *m*; second, when both tangents incline, as shown at *c''* and *d''*.

In Fig. 95 is shown a well-hole connecting two flights, where two

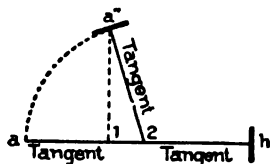


Fig. 96. Finding Angle between Tangents for Bottom Wreath of Fig. 95.

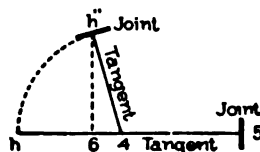


Fig. 97. Finding Angle between Tangents for Upper Wreath of Fig. 95.

portions of unequal pitch occur in both pieces of wreath. The first piece over the tangents *a* and *b* is shown to extend from the square end of the straight rail of the bottom flight, to the joint in the center of the well-hole, the bottom tangent *a''* in this wreath inclining more than the upper tangent *b''*. The other piece of wreath is shown to connect with the bottom one at the joint *h''* in the center of the well-hole, and to extend over tangents *c''* and *d''* to connect with the rail of the upper flight. The relative inclination of the two tangents in this wreath, is the reverse of that of the two tangents of the lower wreath. In the lower piece, the bottom tangent *a''*, as previously stated, inclines considerably more than does the upper tangent *b''*; while in the upper piece, the bottom tangent *c''* inclines considerably less than the upper tangent *d''*.

The question may arise: What causes this? Is it for variation in the inclination of the tangents over the well-hole? It is simply owing to the tangents being used in handrailing to square the joints.

The inclination of the bottom tangent *a''* of the bottom wreath

is clearly shown in the diagram to be determined by the inclination of the bottom flight. The joint at a'' is made square to both the straight rail of the flight and to the bottom tangent of the wreath; the rail and tangent, therefore, must be equally inclined, otherwise the joint will not be a true butt-joint. The same remarks apply to the joint at 5, where the upper wreath is shown jointed to the straight rail of the upper flight. In this case, tangent d'' must be fixed to incline conformably to the inclination of the upper rail; otherwise the joint at 5 will not be a true butt-joint.

The same principle is applied in determining the pitch or inclination over the crown tangents b'' and c'' . Owing to the necessity of jointing the two wreaths, as shown at h , these two tangents must have the same inclination, and therefore must be fixed, as shown from 2 to 4, over the crown of the well-hole.

The tangents as here presented are those of the elevation, not of the face-mould. Tangent a'' is the elevation of the side plan tangent a ; tangents b'' and c'' are shown to be the elevations of the plan tangents b and c ; so, also, is the tangent d'' the elevation of the side plan tangent d .

If this diagram were folded, as Fig. 94 was shown to be in Fig. 93, the tangents of the elevation—namely, a'' , b'' , c'' , d'' —would stand over and above the plan tangents a , b , c , d of the well-hole. In practical work, this diagram must be drawn full size. It gives the correct

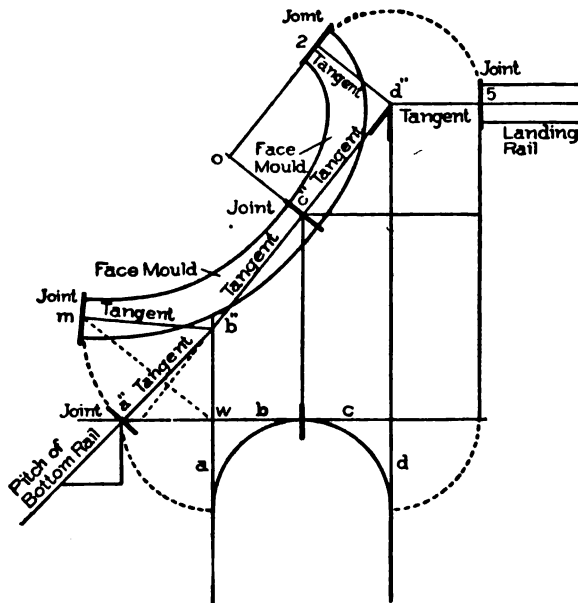


Fig. 98. Diagram of Tangents and Face-Mould for Stair with Well-Hole at Upper Landing.

length to each tangent as required on the face-mould, and furnishes also the data for the lay-out of the mould.

Fig. 96 shows how to find the angle between the tangents of the face-mould for the bottom wreath, which, as shown in Fig. 95, is to span over the first plan quadrant $a b$. The elevation tangents a'' and b'' , as shown, will be the tangents of the mould. To find the angle between the tangents, draw the line $a h$ in Fig. 96; and from a , measure to 2 the length of the bottom tangent a'' in Fig. 95; the length from 2 to h , Fig. 96, will equal the length of the upper tangent b'' , Fig. 95.

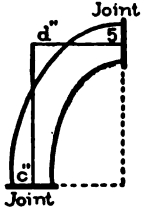


Fig. 96. Drawing Mould when One Tangent is Level and One Inclined over Right-Angled Plan.

From 2 to 1, measure a distance equal to 2-1 in Fig. 95, the latter being found by dropping a perpendicular from w to meet the tangent b'' extended. Upon 1, erect a perpendicular line; and placing the dividers on 2, extend to a ; turn over to the perpendicular at a'' ; connect this point with 2, and the line will be the bottom tangent as required on the face-mould. The upper tangent will be the line 2- h , and the angle between the two lines is shown at 2. Make the joint at h square to 2- h , and at a'' square to a'' -2.

The mould as it appears in Fig. 96 is complete, except the curve, which is comparatively a small matter to put on, as will be shown further on. The main thing is to find the angle between the tangents, which is shown at 2, to give them the direction to square the joints.

In Fig. 97 is shown how to find the angle between the tangents c'' and d'' shown in Fig. 95, as required on the face-mould. On the line h -5, make h -4 equal to the length of the bottom tangent of the wreath, as shown at h'' -4 in Fig. 95; and 4-5 equal to the length of the upper tangent d'' . Measure from 4 the distance shown at 4-6 in Fig. 95, and place it from 4 to 6 as shown in Fig. 97; upon 6 erect a

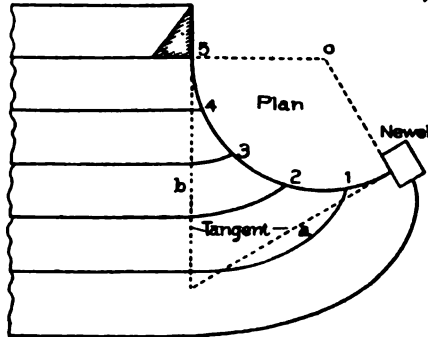


Fig. 100. Plan of Curved Steps and Stringer at Bottom of Stair.

perpendicular line. Now place the dividers on 4; extend to h ; turn over to cut the perpendicular in h'' ; connect this point with 4, and the angle shown at 4 will be the angle required to square the joints of the wreath as shown at h'' and 5, where the joint at 5 is shown drawn square to the line 4-5, and the joint at h'' square to the line 4 h'' .

[illegible]

The face-mould, as here presented, will further help toward an understanding of the layout of face-moulds as shown in Figs. 96

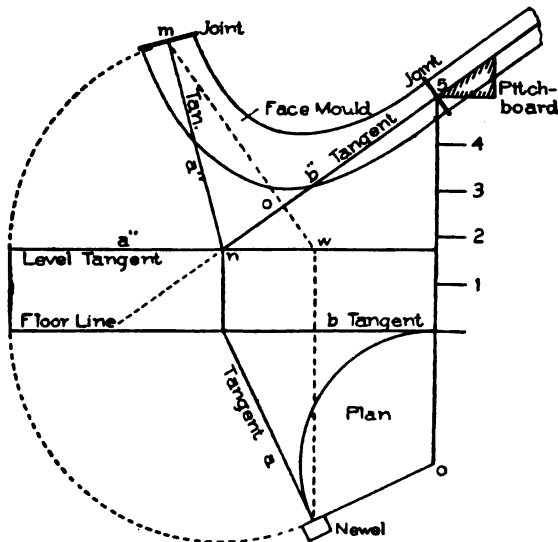


Fig. 101. Finding Angle between Tangents for Squaring Joints of Ramped Wreath.

and 97. It will be observed that the pitch of the bottom rail is continued from a'' to b'' , a condition caused by the necessity of jointing the wreath to the end of the straight rail at a'' , the joint being made square to both the straight rail and the bottom tangent a'' . From b'' a line is drawn to d'' , which is a fixed point determined by the number of risers in the well-hole. From point d'' , the level tangent $d'' 5$ is drawn in line with the level rail of the landing; thus the pitch-line of the tangents over the well-hole is found, and, as was shown in the explanation of Fig. 95, the tangents as here presented will be those required on the face-mould to square the joints of the wreath.

In Fig. 98 the tangents of the face-mould for the bottom wreath are shown to be a'' and b'' . To place tangent a'' in position on the face-mould, it is revolved, as shown by the arc, to m , cutting a line

previously drawn from w square to the tangent b'' extended. Then, by connecting m to b'' , the bottom tangent is placed in position on the face-mould. The joint at m is to be made square to it; and the joint at c , the other end of the mould, is to be made square to the tangent b'' .

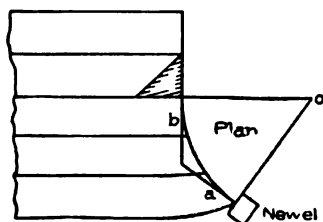


Fig. 102. Bottom Steps with Obtuse-Angle Plan.

The upper piece of wreath in this example is shown to have tangent c'' inclining, the inclination being the same as that of the upper tangent b'' of the bottom wreath, so that the joint at c'' , when made square to both tangents, will butt square when put together. The tangent d'' is shown to be level, so that the joint at 5, when squared with it, will butt square with the square end

of the level-landing rail. The level tangent is shown revolved to its position on the face-mould, as from 5 to 2. In this last position, it will be observed that its angle with the inclined tangent c'' is a right angle; and it should be remembered that in every similar case where one tangent inclines and one is level over a square-angle plan tangent, the angle between the two tangents will be a right angle on the face-mould. A knowledge of this principle will enable the student to draw the mould for this wreath, as shown in Fig. 99, by merely drawing two lines perpendicular to each other, as $d'' 5$ and $d'' c''$, equal respectively to the level tangent $d'' 5$ and the inclined tangent c'' in Fig. 98. The joint at 5 is to be made square to $d'' 5$; and that at c'' , to $d'' c''$. Comparing this figure with the face-mould as shown for the upper wreath in Fig. 98, it will be observed that both are alike.

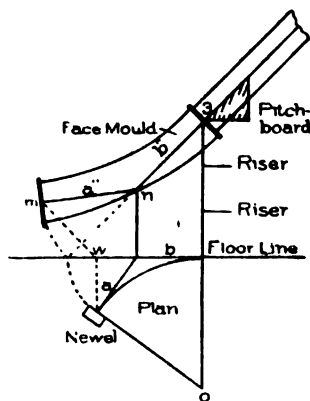


Fig. 103. Developing Face-Mould, Obtuse-Angle Plan.

In practical work the stair-builder is often called upon to deal with cases in which the conditions of tangents differ from all the examples thus far given. An instance of this sort is shown in Fig. 100, in which the angles between the tangents on the plan are acute.

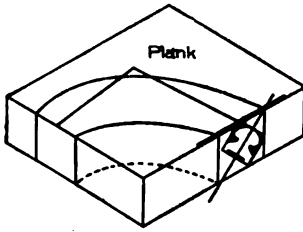


Fig. 104. Cutting Wreath from Plank.

In all the preceding examples, the tangents on the plan were at right angles; that is, they were square to one another.

Fig. 100 is a plan of a few curved steps placed at the bottom of a stairway with a curved stringer, which is struck from a center *o*. The plan tangents *a* and *b* are shown to form an acute angle with each other. The rail above a plan of this design is usually ramped at the bottom end, where it intersects the newel post, and, when so treated, the bottom tangent *a* will have to be level.

In Fig. 101 is shown how to find the angle between the tangents on the face-mould that gives them the correct direction for squaring the joints of the wreath when it is determined to have it ramped. This figure must be drawn full size. Usually an ordinary drawing-board will answer the purpose. Upon the board, reproduce the plan of the tangents and curve of the center line of rail as shown in Fig. 100. Measure the height

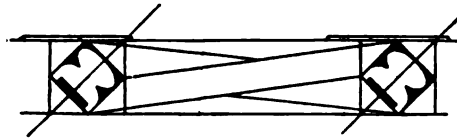


Fig. 105. Wreath Twisted, Ready to be Moulded.

of 5 risers, as shown in Fig. 101, from the floor line to 5; and draw the pitch of the flight adjoining the wreath, from 5 to the floor line. From the newel, draw the dotted line to *w*, square to the floor line; from *w*, draw the line *wm*, square to the pitch-line *b''*. Now take the length of the bottom level tangent on a trammel, or on dividers if large enough, and extend it from *n* to *m*, cutting the line drawn previously from

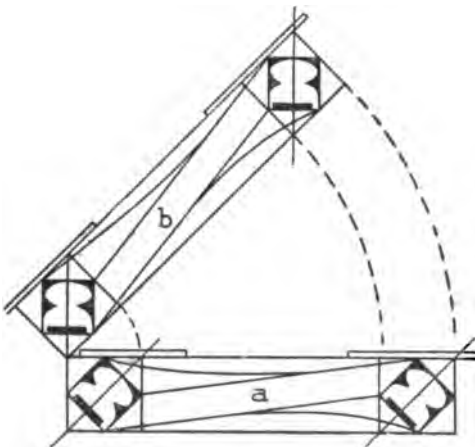


Fig. 106. Twisted Wreath Raised to Position, with Sides Plumb.

of 5 risers, as shown in Fig. 101, from the floor line to 5; and draw the pitch of the flight adjoining the wreath, from 5 to the floor line. From the newel, draw the dotted line to *w*, square to the floor line; from *w*, draw the line *wm*, square to the pitch-line *b''*. Now take the length of the bottom level tangent on a trammel, or on dividers if large enough, and extend it from *n* to *m*, cutting the line drawn previously from

w , at m . Connect m to n as shown by the line a'' . The intersection of this line with b'' determines the angle between the two tangents a'' and b'' of the face-mould, which gives them the correct direction as required on the face-mould for squaring the joints. The joint at m is made square to tangent a'' ; and the joint at n , to tangent b'' .

In Fig. 102 is presented an example of a few steps at the bottom of a stairway in which the tangents of the plan form an obtuse angle with each other. The curve of the central line of the rail in this case will be less than a quadrant, and, as shown, is struck from the center o , the curve covering the three first steps from the newel to the springing.

In Fig. 103 is shown how to develop the tangents of the face-mould. Reproduce the tangents and

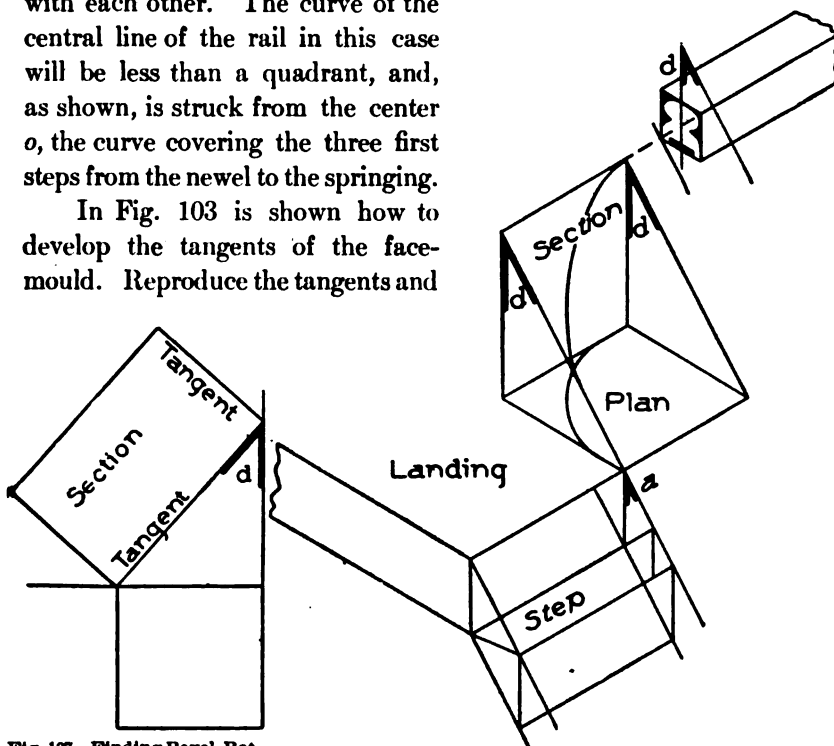


Fig. 107. Finding Bevel, Bottom Tangent Inclined, Top One Level.

Fig. 108. Application of Bevels in Fitting Wreath to Rail.

curve of the plan in full size. Fix point 3 at a height equal to 3 risers from the floor line; at this point place the pitch-board of the flight to determine the pitch over the curve as shown from 3 through b'' to the floor line. From the newel, draw a line to w , square to the floor line; and from w , square to the pitch-line b'' , draw the line $w m$; connect m to n . This last line is the development of the bottom plan tangent a ; and the line b'' is the development of the plan tangent

b ; and the angle between the two lines a'' and b'' will give each line its true direction as required on the face-mould for squaring the joints

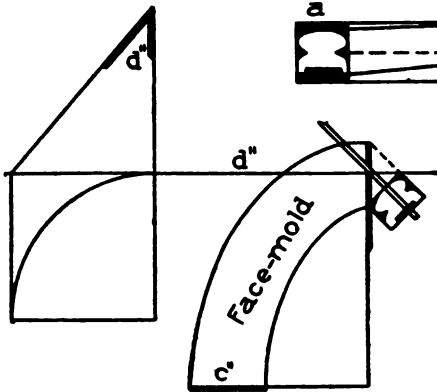


Fig. 100. Face-Mould and Bevel for Wreath, Bottom Tangent Level, Top One Inclined.

of the wreath, as shown at m to connect square with the newel, and at 3 to connect square to the rail of the connecting flight.

The wreath in this example follows the nosing line of the steps

without being ramped as it was in the examples shown in Figs. 100 and 101. In those figures the bottom tangent a was level, while in Fig. 103 it inclines equal to the pitch of the upper tangent b'' and of the flight adjoining. In other words, the method shown in Fig. 101 is applied to a construction in which the wreath is ramped; while in Fig. 103 the method is applicable to a wreath following the nosing line all along the curve to the newel.

The stair-builder is supposed to know how to construct a wreath under both conditions, as the conditions are usually determined by the Architect.

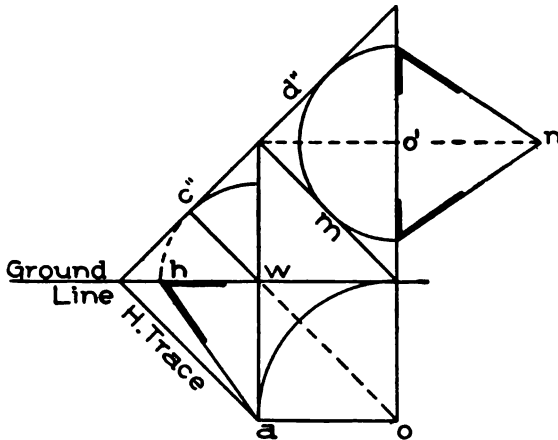


Fig. 110. Finding Bevels for Wreath with Two Equally Inclined Tangents.

are out of plumb. In the upper part of the figure, the wreath *b* is shown placed in its position upon the plane of the section, where its sides are seen to be plumb. It is evident, as shown in the relative position of the wreath in this figure, that, if the bevel is the correct angle of the plane of the section whereon the wreath *b* rests in its ascent over the well-hole, the wreath will in

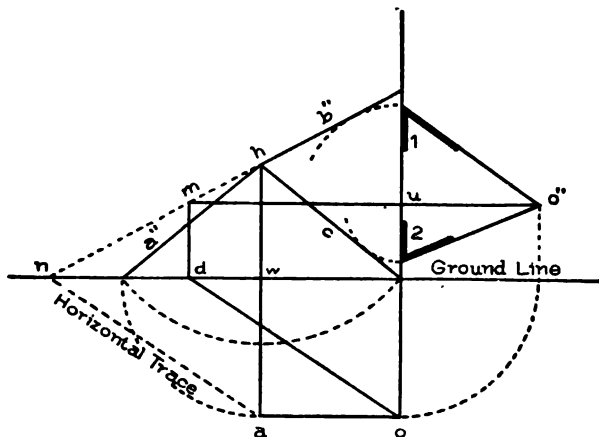


Fig. 113. Finding Bevel Where Upper Tangent Inclines Less Than Lower One.

that case have its sides plumb all along when in position. It is for this purpose that the bevels are needed.

A method of finding the bevels for *all wreaths* (which is considered rather difficult) will now be explained:

First Case. In Fig. 107 is shown a case where the bottom tangent of a wreath is inclining, and the top one level, similar to the top wreath shown in Fig. 98. It has already been noted that the plane of the section for this kind of wreath inclines to one side only; therefore one bevel only will be required to square it, which is shown at *d*, Fig. 107. A view of this plane is given in Fig. 108; and the bevel *d*, as there shown, indicates the angle of the inclination, which also is the bevel required to square the end *d* of the wreath. The bevel is shown applied to the end of the landing rail in exactly the same manner in which it is to be applied to the end of the wreath. The true bevel for this wreath is found at the upper angle of the pitch-board. At the end *a*, as already stated, no bevel is required, owing to the plane inclining in one direction only. Fig. 109 shows a face-mould and bevel for a wreath with the bottom tangent level and the top tangent inclining, such as the piece at the bottom connecting with the landing rail in Fig. 94.

Second Case. It may be required to find the bevels for a wreath having two equally inclined tangents. An example of this kind also is shown in Fig. 94, where both the tangents c'' and d'' of the upper

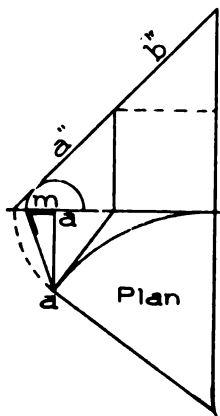


Fig. 114. Finding Bevel Where Tangents Incline Equally over Obtuse-Angle Plan.

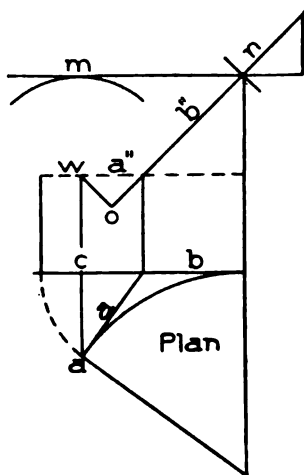


Fig. 115. Same Plan as in Fig. 114, but with Bottom Tangent Level.

wreath incline equally. Two bevels are required in this case, because the plane of the section is inclined in two directions; but, owing to the inclinations being alike, it follows that the two will be the same. They are to be applied to both ends of the wreath, and, as shown in

Fig. 105, in the same direction—namely, toward the inside of the wreath for the bottom end, and toward the outside for the upper end.

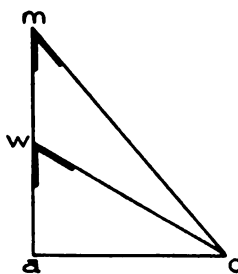


Fig. 116. Finding Bevels for Wreath of Fig. 115.

In Fig. 110 the method of finding the bevels is shown. A line is drawn from w to c'' , square to the pitch of the tangents, and turned over to the ground line at h , which point is connected to a as shown. The bevel is at h . To show that equal tangents have equal bevels, the line m is drawn, having the same inclination as the bottom tangent c'' , but in another direction. Place the dividers on o' , and turn to touch the lines d'' and m , as shown by the semicircle. The line from o' to n is equal to the side plan tangent

w a , and both the bevels here shown are equal to the one already found. They represent the angle of inclination of the plane whereon the wreath ascends, a view of which is given in Fig. 111, where the plane is shown to incline equally in two directions. At both ends is shown a section of a rail; and the bevels are applied to show how, by means of them, the wreath is *squared* or *twisted* when winding around the well-hole and ascending upon the plane of the section. The view given in this figure will enable the student to understand the nature of the bevels found in Fig. 110 for a wreath having two equally inclined tangents; also for all other wreaths of equally inclined tangents, in that every wreath in such case is assumed to rest upon an inclined plane in its ascent over the well-hole, the bevel in every case being the angle of the inclined plane.

Fig. 117. Upper Tangent Inclined, Lower Tangent Level, Over Acute-Angle Plan.

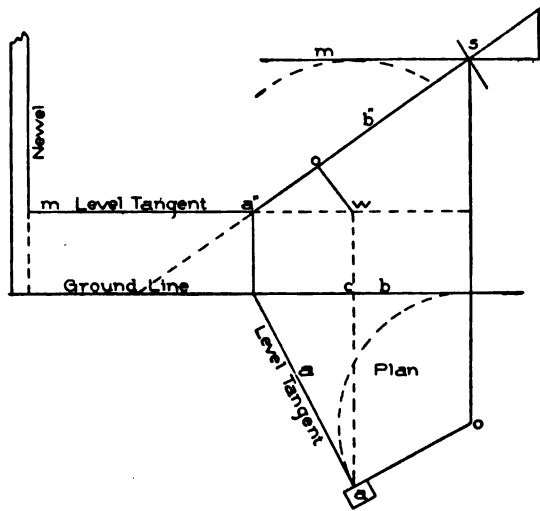


Fig. 117. Upper Tangent Inclined, Lower Tangent Level, Over Acute-Angle Plan.

Third Case. In this example, two unequal tangents are given, the upper tangent inclining more than the bottom one. The method shown in Fig. 110 to find the bevels for a wreath with two equal tangents, is applicable to all conditions of variation in the inclination of the tangents. In Fig. 112 is shown a case where the upper tangent d'' inclines more than the bottom one c'' . The method in all cases is to continue the line of the upper tangent d'' , Fig. 112, to the ground line as shown at n ; from n , draw a line to a , which will be the horizontal trace of the plane. Now, from o , draw a line parallel to an , as shown from o to d , upon d , erect a perpendicular line to cut the tangent d'' , as shown, at m ; and draw the line $mu o''$. Make uo'' equal to the length of the plan tangent as shown by the arc from o . Put one

touch the pitch of tangents, and turn over as shown to m ; connect m to a . The bevel at m will be the only one required for this wreath, but it will have to be applied to both ends, owing to the two tangents being inclined.

Sixth Case. In this case we have one tangent inclining and one tangent level, over an acute-angle plan.

In Fig. 115 is shown the same plan as in Fig. 114; but in this

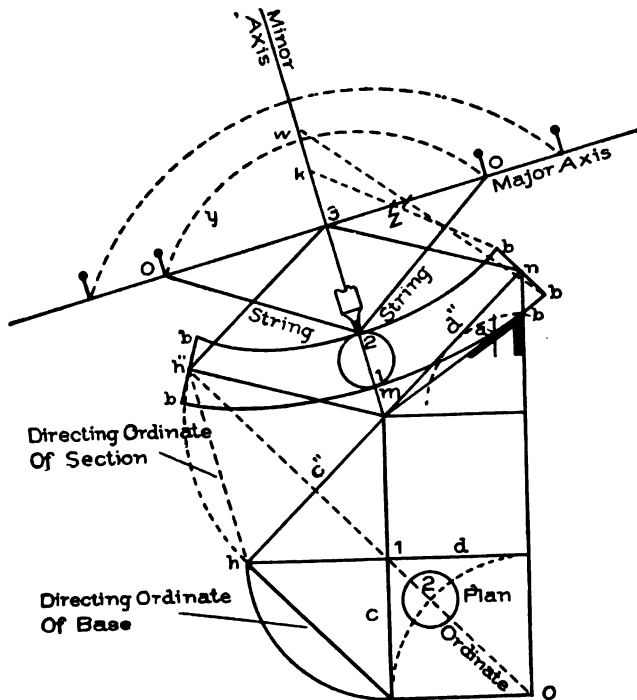


Fig. 119. Laying Out Curves on Face-Mould with Pins and String.

case the bottom tangent a'' is to be a level tangent. Probably this condition is the most commonly met with in wreath construction at the present time. A small curve is considered to add to the appearance of the stair and rail; and consequently it has become almost a "fad" to have a little curve or stretch-out at the bottom of the stairway, and in most cases the rail is ramped to intersect the newel at right angles instead of at the pitch of the flight. In such a case, the bottom tangent a'' will have to be a level tangent, as shown at a'' in Fig. 115, the pitch of the flight being over the plan tangent b only.

To find the bevels when tangent b'' inclines and tangent a'' is level, make $a c$ in Fig. 116 equal to $a c$ in Fig. 115. This line will be the base of the two bevels.

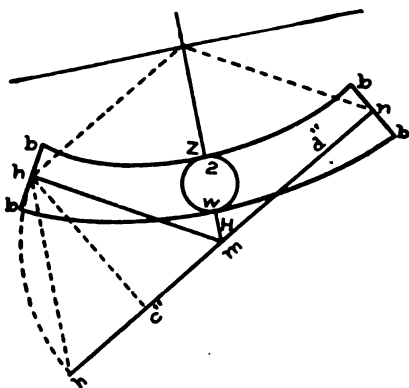


Fig. 120. Simple Method of Drawing Curves on Face-Mould.

Upon a , erect the line $a w m$ at right angles to $a c$; make $a w$ equal to $o w$ in Fig. 115; connect w and c ; the bevel at w will be the one to apply to tangent b'' at n where the wreath is joined to the rail of the flight. Again, make $a m$ in Fig. 116 equal the distance shown in Fig. 115 between w and m , which is the full height over which tangent b'' is inclined; connect m to

c in Fig. 116, and at m is the bevel to be applied to the level tangent a'' .

Seventh Case.

In this case, illustrated in Fig. 117, the upper tangent b'' is shown to incline, and the bottom tangent a'' to be level, over an acute-angle plan. The plan here is the same as that in Fig. 100, where a curve is shown to stretch out from the line of the straight stringer at the bottom of a flight to a newel, and is large enough to contain five treads, which

are gracefully rounded to cut the curve of the central line of rail in 1, 2, 3, 4. This curve also may be used to connect a landing rail to a

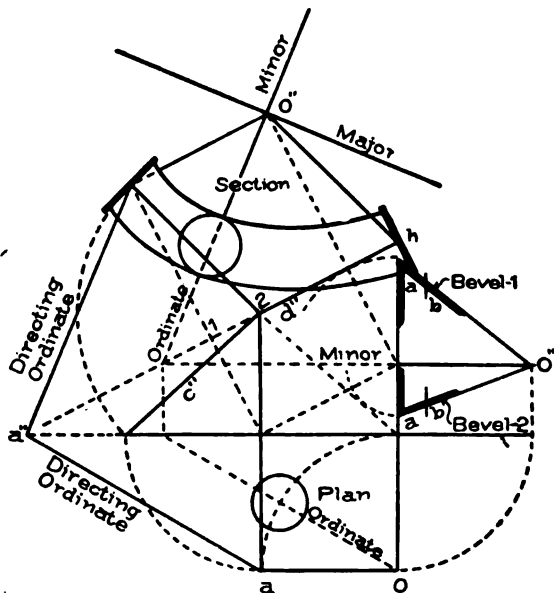


Fig. 121. Tangents, Bevels, Mould-Curves, etc., from Bottom Wreath of Fig. 96, in which Upper Tangent Inclines Less than Lower One.





SHOOTING LODGE FOR MR. ALBERT G. MEIER, HIGHGATE, MO.

Dean & Dean, Architects, Chicago, Ill.

Walls of Logs, and Roof of Split Shingles. Built in 1907.

flight, either at top or bottom, when the plan is acute-angled, as will be shown further on.

To find the bevels—
for there will be two
bevels necessary for this
wreath, owing to one
tangent b'' being inclined
and the other tangent a''
being level—make $a'c$,
Fig. 118, equal to $a'c$ in
Fig. 117, which is a line
drawn square to the
ground line from the
newel and shown in all
preceding figures to have
been used for the base
of a triangle containing
the bevel. Make aw in
Fig. 118 equal to wo in

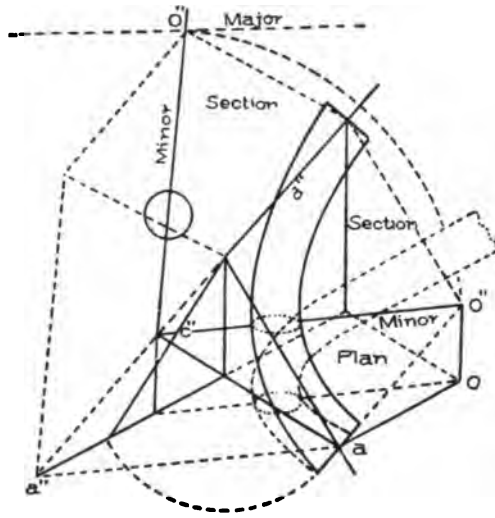


Fig. 122. Developed Section of Plane Inclining Unequally in Two Directions.

Fig. 117, which is a line drawn square to the inclined tangent b'' from w ; connect w and c in Fig. 118. The bevel shown at w will be the one to be applied to the joint 5 on tangent b'' , Fig. 117. Again, make am

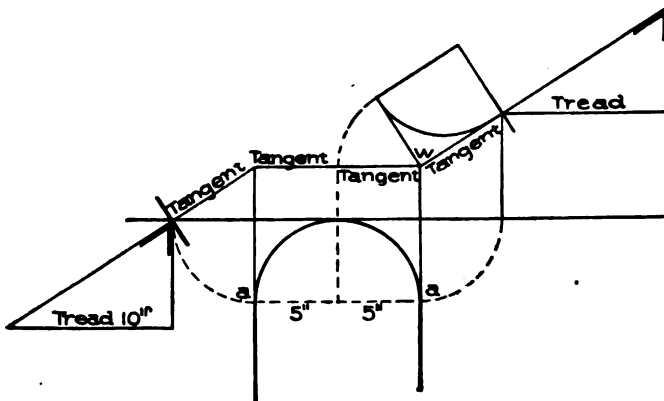


Fig. 123. Arranging Risers around Well-Hole on Level-Landing Stair, with Radius of Central Line of Rail One-Half Width of Tread.

in Fig. 118 equal to the distance shown in Fig. 117 between the line representing the level tangent and the line $m'5$, which is the height that

tangent b'' is shown to rise; connect m to c in Fig. 118; the bevel shown at m is to be applied to the end that intersects with the newel as shown at m in Fig. 117.

The wreath is shown developed in Fig. 101 for this case; so that, with Fig. 100 for plan, Fig. 101 for the development of the wreath, and Figs. 117 and 118 for finding the bevels, the method of handling any similar case in practical work can be found.

How to Put the Curves on the Face-Mould.

It has been shown how to find the angle between the tangents of the face-mould, and that the angle is for the purpose of squaring the joints at the ends of the wreath. In Fig. 119 is shown how to lay out the curves by means of pins and a string—a very common practice among stair-builders. In this example the face-mould has equal tangents as shown

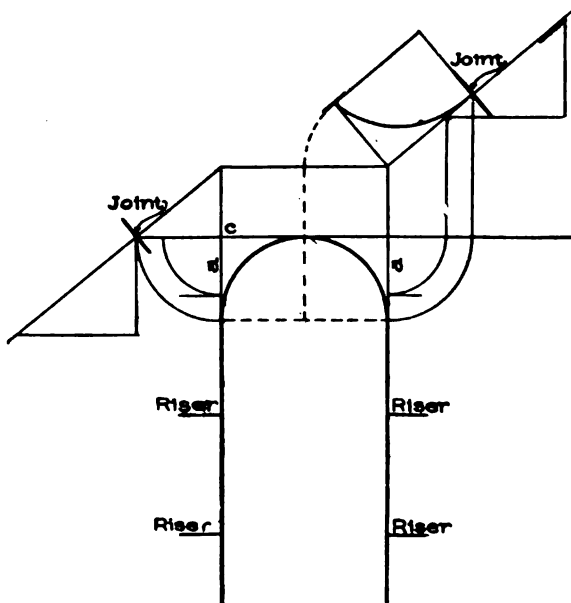


Fig. 124. Arrangement of Risers Around Well-Hole with Radius Larger Than One-Half Width of Tread.

at c'' and d'' . The angle between the two tangents is shown at m as it will be required on the face-mould. In this figure a line is drawn from m parallel to the line drawn from h , which is marked in the diagram as "Directing Ordinate of Section." The line drawn from m will contain the minor axes; and a line drawn through the corner of the section at 3 will contain the major axes of the ellipses that will constitute the curves of the mould.

The *major* is to be drawn square to the *minor*, as shown. Place, from point 3, the circle shown on the minor, at the same distance as the circle in the plan is fixed from the point o . The diameter

of this circle indicates the width of the curve at this point. The width at each end is determined by the bevels. The distance a b , as shown

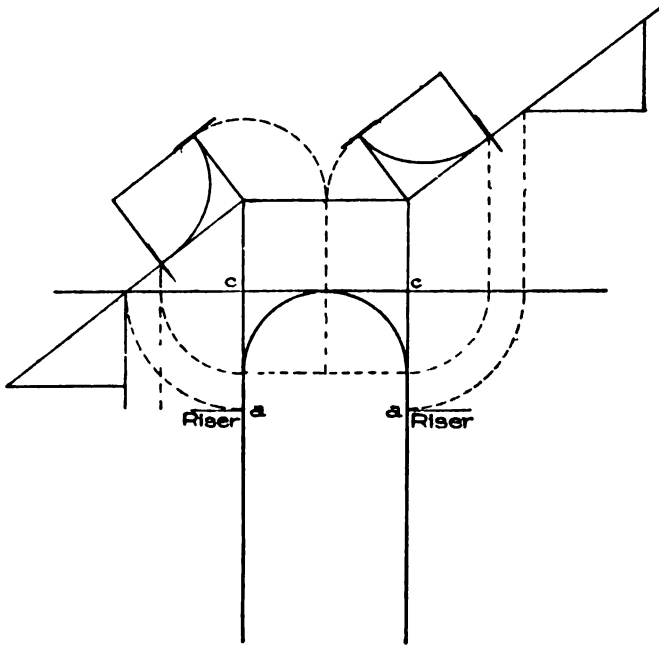


Fig. 125. Arrangement of Risers around Well-Hole, with Risers Spaced Full Width of Tread.

upon the long edge of the bevel, is equal to $\frac{1}{2}$ the width of the mould, and is the hypotenuse of a right-angled triangle whose base is $\frac{1}{2}$ the width of the rail. By placing this dimension on each side of n , as shown at b

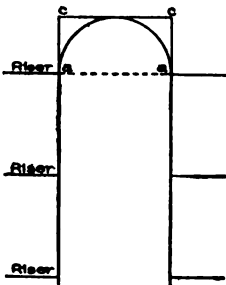


Fig. 126. Plan of Stair Shown in Fig. 123.

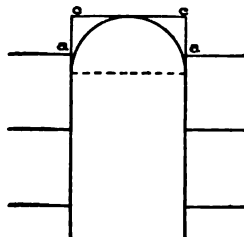


Fig. 127. Plan of Stair Shown in Fig. 124.

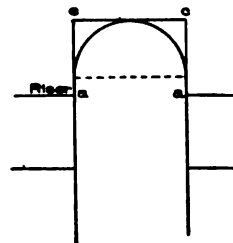


Fig. 128. Plan of Stair Shown in Fig. 125.

and b , and on each side of h'' on the other end of the mould, as shown also at b and b , we obtain the points b 2 b on the inside of the curve, and

the points b 1 b on the outside. It will now be necessary to find the elliptical curves that will contain these points; and before this can be done, the exact length of the *minor* and *major* axes respectively must be determined. The length of the minor axis for the inside curve will be the distance shown from 3 to 2; and its length for the outside will be the distance shown from 3 to 1.

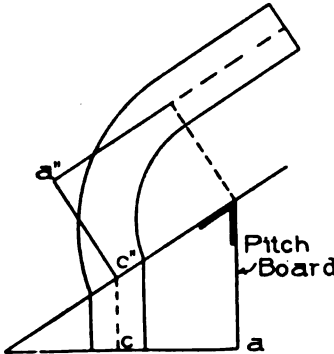


Fig. 129. Drawing Face-Mould for Wreath from Pitch-Board.

To find the length of the major axis for the inside, take the length of half the minor for the inside on the dividers: place one leg on b , extend to cut the major in z , continue to the minor as shown at k . The distance from b to k

will be the length of the semi-major axis for the inside curve.

To draw the curve, the points or *foci* where the pins are to be fixed must be found on the major axis. To find these points, take the length of b k (which is, as previously found, the exact length of

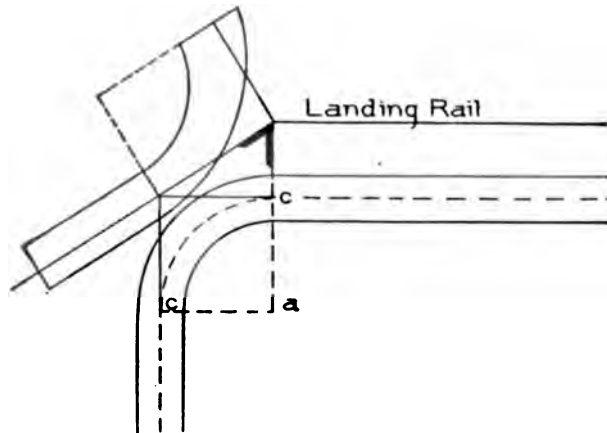


Fig. 130. Development of Face-Mould for Wreath Connecting Rail of Flight with Level-Landing Rail.

the semi-major for the inside curve) on the dividers; fix one leg at 2, and describe the arc Y , cutting the major where the pins are shown fixed, at o and o . Now take a piece of string long enough to form a

loop around the two and extending, when tight, to 2, where the pencil is placed; and, keeping the string tight, sweep the curve from *b* to *b*.

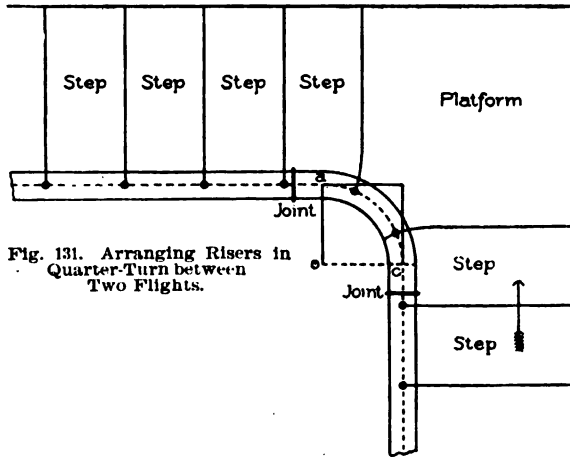


Fig. 131. Arranging Risers in Quarter-Turn between Two Flights.

The same method, for finding the *major* and *foci* for the outside curve, is shown in the diagram. The line drawn from *b* on the outside of the joint at *n*, to *w*, is the semi-major for the outside curve; and the

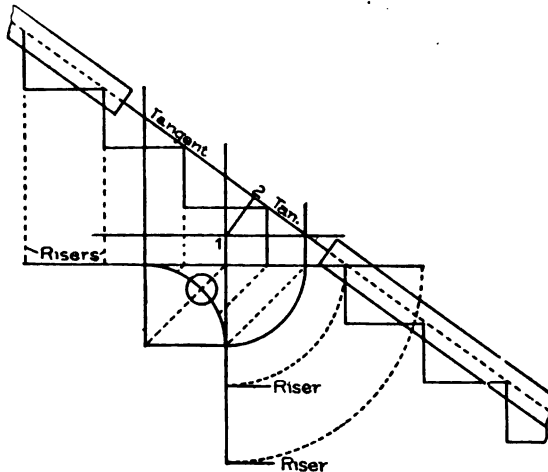


Fig. 132. Arrangement of Risers around Quarter-Turn Giving Tangents Equal Pitch with Connecting Flight.

points where the outside pins are shown on the major will be the *foci*. To draw the curves of the mould according to this method, which

is a scientific one, may seem a complicated problem; but once it is understood, it becomes very simple. A simpler way to draw them, however, is shown in Fig. 120.

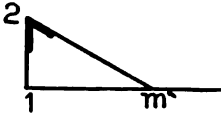


Fig. 133. Finding Bevel for Wreath of Plan, Fig. 132.

The width on the minor and at each end will have to be determined by the method just explained in connection with Fig. 119. In Fig 120, the points *b* at the ends, and the points in which the circumference of the circle cuts the minor axis, will be points contained in the curves, as already explained. Now take a flexible lath; bend it to touch *b*, *z*, and *b* for the inside curve, and *b*, *w*, and *b* for the outside curve. This method is handy where the curve is comparatively flat, as in the example here shown; but where the mould has a sharp curva-

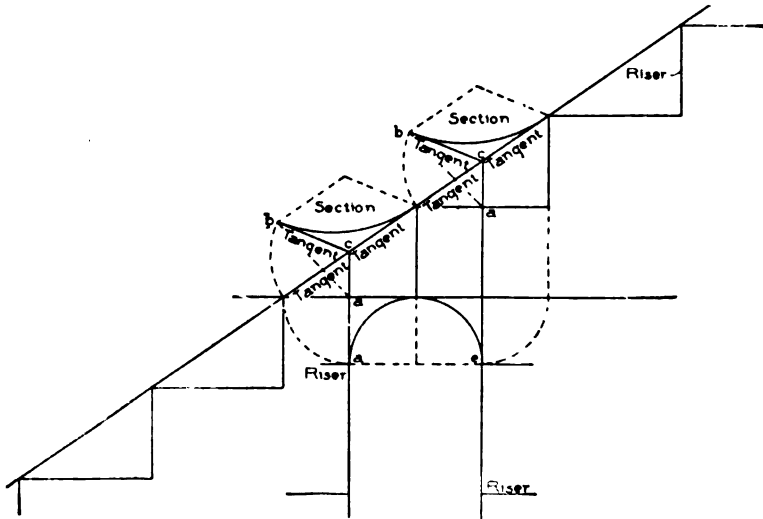


Fig. 134. Well-Hole with Riser in Center. Tangents of Face-Mould, and Central Line of Rail, Developed.

ture, as in case of the one shown in Fig. 101, the method shown in Fig. 119 must be adhered to.

With a clear knowledge of the above two methods, the student will be able to put curves on any mould.

The mould shown in these two diagrams, Figs. 119 and 120, is for the upper wreath, extending from *h* to *n* in Fig. 94. A practical handrailer would draw only what is shown in Fig. 120. He would

take the lengths of tangents from Fig. 94, and place them as shown at $h m$ and $m n$. By comparing Fig. 120 with the tangents of the upper wreath in Fig. 94, it will be easy for the student to understand

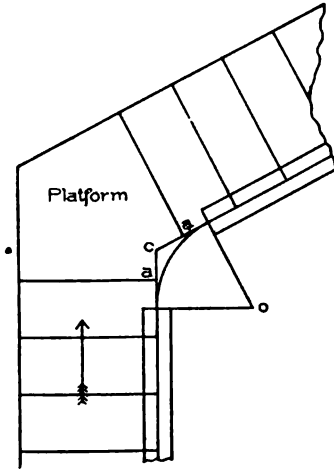


Fig. 135. Arrangement of Risers in Stair with Obtuse-Angle Plan.

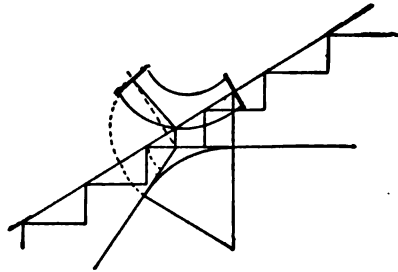
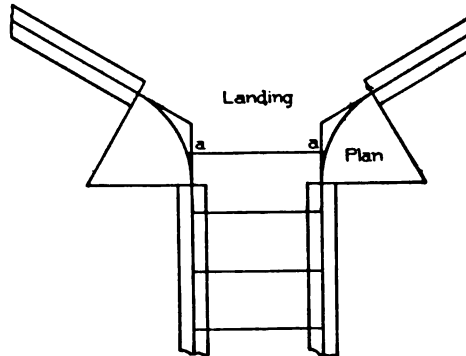


Fig. 136. Arrangement of Risers in Obtuse-Angle Plan, Giving Equal Pitch over Tangents and Flights. Face-Mould Developed.

the remaining lines shown in Fig. 120. The bevels are shown applied to the mould in Fig. 105, to give it the twist. In Fig. 106, is shown how, after the rail is twisted and placed in position over and above the quadrant $c d$ in Fig. 94, its sides will be plumb.

In Fig. 121 are shown the tangents taken from the bottom wreath in Fig. 95. It was shown how to develop the section and find the angle for the tangents in the face-mould, Fig. 137. Arrangement of Risers in Flight with Curve at Landing.



shown in Fig. 119 for putting on the curves, would be the most suitable.

Fig. 121 is presented more for the purposes of study than as a method of construction. It contains all the lines made use of to find

the developed section of a plane inclining unequally in two different directions, as shown in Fig. 122.

Arrangement of Risers in and around Well-Hole. An important matter in wreath construction is to have a knowledge of how to

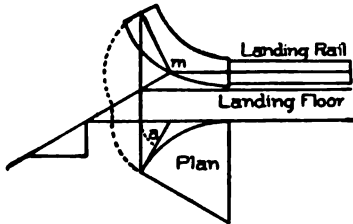


Fig. 138. Development of Face-Moulds for Plan, Fig. 137.

arrange the risers in and around a well-hole. A great deal of labor and material is saved through it; also a far better appearance to the finished rail may be secured.

In level-landing stairways, the easiest example is the one shown in Fig. 123, in which the radius of the central line of rail is made equal to one-half the width of a tread. In the diagram the radius is shown to be 5 inches, and the treads 10 inches. The risers are placed in the springing, as at a and a' . The elevation of the tangents by this arrangement will be, as shown, one level and one inclined, for each piece of wreath. When in this position, there is no trouble in finding the angle of the tangent as required on the face-mould, owing to that angle, as in every such case, being a right angle, as shown at w ; also no special bevel will have to be found, because the upper bevel of the pitch-board contains the angle required.

The same results are obtained in the example shown in Fig. 124, in which the radius of the well-hole is larger than half the width of a tread, by placing the riser a at a distance from c equal to half the width of a tread, instead of at the springing as in the preceding example.

In Fig. 125 is shown a case where the risers are placed at a distance from c equal to a full tread, the effect in respect to the tangents of the face-mould and bevel being the same as in the two preceding examples. In Fig. 126 is shown the plan of Fig. 123; in Fig. 127, the plan of Fig. 124; and in Fig. 128, the plan of Fig. 125. For the wreaths shown in all these figures, there will be no necessity of *springing* the plank, which is a term used in handrailing to denote the twisting of the wreath; and no other bevel than the one at the upper end of the pitch-board will be required. This type of wreath, also, is the one that is required at the top of a landing when the rail of the flight intersects with a level-landing rail.

In Fig. 129 is shown a very simple method of drawing the face-mould for this wreath from the pitch-board. Make ac equal to the radius of the plan central line of rail as shown at the curve in Fig. 130. From where line $c c''$ cuts the long side of the pitch-board, the line $c'' a''$ is drawn at right angles to the long edge, and is made equal to the length of the plan tangent ac , Fig. 130. The curve is drawn by means of pins and string or a trammel.

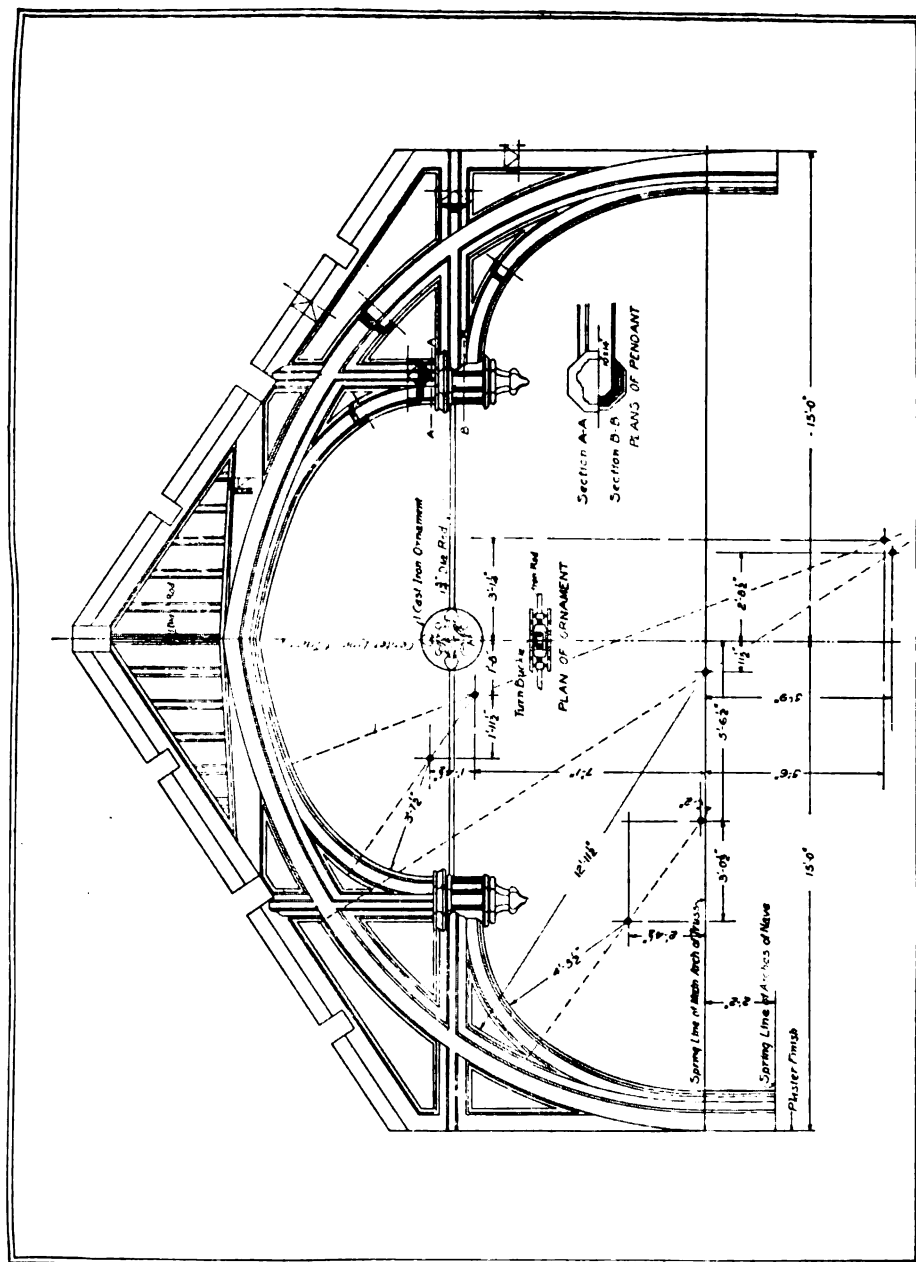
In Fig. 131 is shown a quarter-turn between two flights. The correct method of placing the risers in and around the curve, is to put the last one in the first flight one-half a step from springing c , and the first one in the second flight one-half a step from a , leaving a space in the curve equal to a full tread. By this arrangement, as shown in Fig. 132, the pitch-line of the tangents will equal the pitch of the connecting flight, thus securing the second easiest condition of tangents for the face-mould—namely, as shown, two equal tangents. For this wreath, only one bevel will be needed, and it is made up of the radius of the plan central line of the rail oc , Fig. 131, for base, and the line 1-2, Fig. 132, for altitude, as shown in Fig. 133.

The bevel shown in this figure has been previously explained in Figs. 105 and 106. It is to be applied to both ends of the wreath.

The example shown in Fig. 134 is of a well-hole having a riser in the center. If the radius of the plan central line of rail is made equal to one-half a tread, the pitch of tangents will be the same as of the flights adjoining, thus securing two equal tangents for the two sections of wreath. In this figure the tangents of the face-mould are developed, and also the central line of the rail, as shown over and above each quadrant and upon the pitch-line of tangents.

The same method may be employed in stairways having obtuse-angle and acute-angle plans, as shown in Fig. 135, in which two flights are placed at an obtuse angle to each other. If the risers shown at a and a are placed one-half a tread from c , this will produce in the elevation a pitch-line over the tangents equal to that over the flights adjoining, as shown in Fig. 136, in which also is shown the face-mould for the wreath that will span over the curve from one flight to another.

In Fig. 137 is shown a flight having the same curve at a landing. The same arrangement is adhered to respecting the placing of the risers, as shown at a and a . In Fig. 138 is shown how to develop the face-moulds.





THE STEEL SQUARE

INTRODUCTORY

The Standard Steel Square has a *blade* 24 inches long and 2 inches wide, and a *tongue* from 14 to 18 inches long and $1\frac{1}{2}$ inches wide.

The blade is at right angles to the tongue.

The *face* of the square is shown in Fig. 1. It is always stamped with the manufacturer's name and number.

The reverse is the *back* (see Fig. 2).

The longer arm is the *blade*; the shorter arm, the *tongue*.

In the center of the tongue, on the face side, will be found two parallel lines divided into spaces (see Fig. 1); this is the *octagon scale*.

The spaces will be found numbered 10, 20, 30, 40, 50, 60, and 70, when the tongue is 18 inches long.

To draw an octagon of 8 inches square, draw a square 8 inches each way, and draw a perpendicular and a horizontal line through its center.

To find the length of the octagon side, place one point of a compass on any of the main divisions of the scale, and the other point of the compass on the eighth subdivision; then step this length off on each side of the center lines on the side of the square, which will give the points from which to draw the octagon lines.

The diameter of the octagon must equal in inches the number of spaces taken from the square.

On the opposite side of the tongue, in the center, will be found the *brace rule* (see Fig. 3). The fractions denote the *rise* and *run* of the brace, and the decimals the *length*. For example, a brace of 36 inches run and 36 inches rise, will have a length of 50.91 inches; a brace of 42 inches run and 42 inches rise, will have a length of 59.40 inches; etc.

On the back of the blade (Fig. 4) will be found the *board measure*, where eight parallel lines running along the length of the blade are shown and divided at every inch by cross-lines. Under 12, on the outer edge of the blade, will be found the various lengths of the boards, as 8, 9, 10, 11, 12, etc. For example, take a board 14 feet long and 9

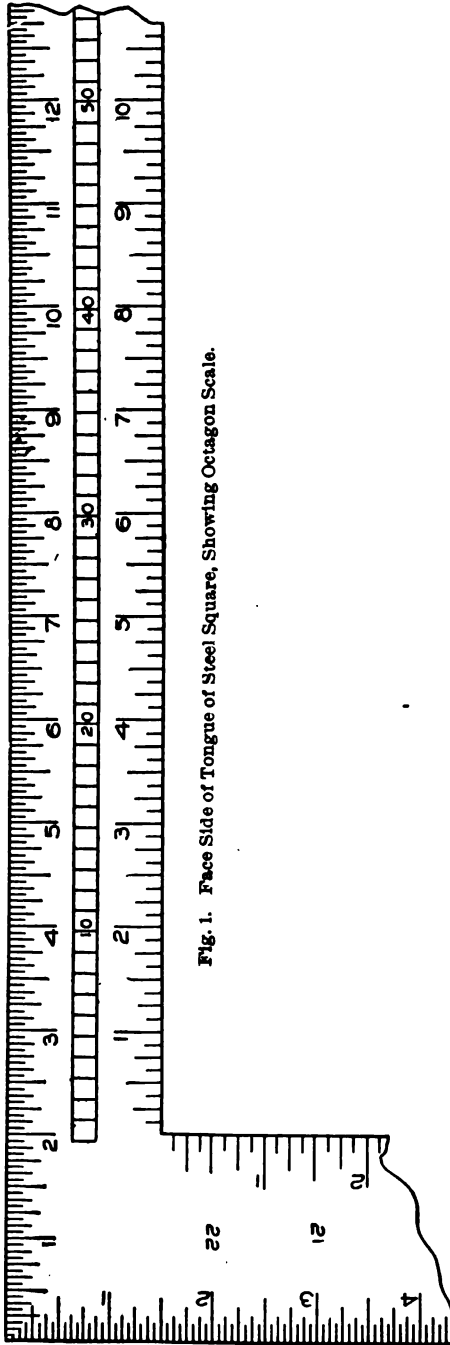


Fig. 1. Face Side of Tongue of Steel Square, Showing Octagon Scale.

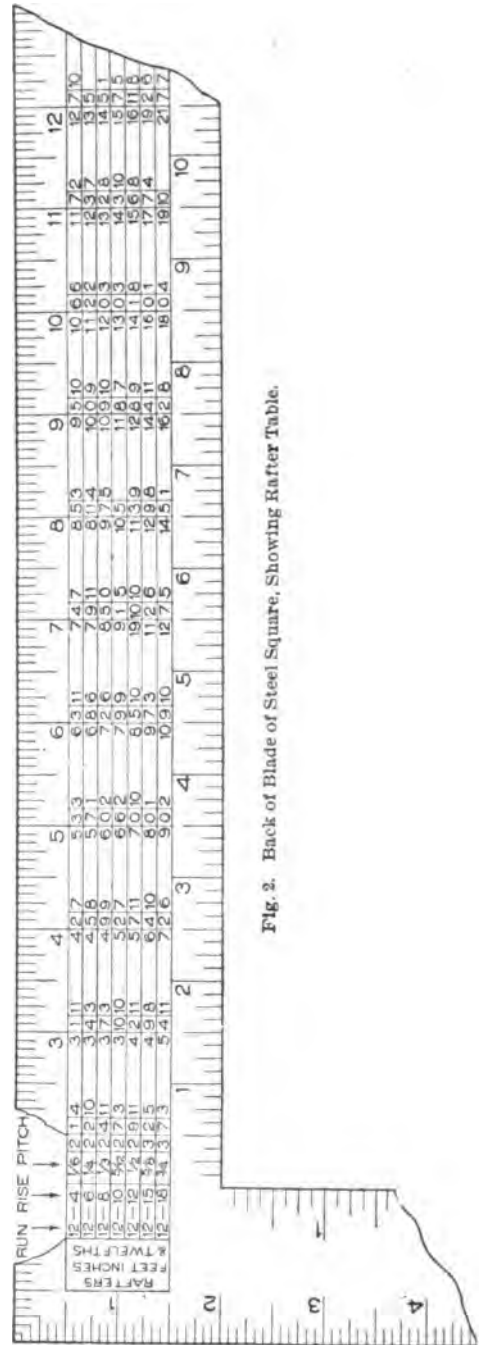


Fig. 2. Back of Blade of Steel Square, Showing Rafter Table.

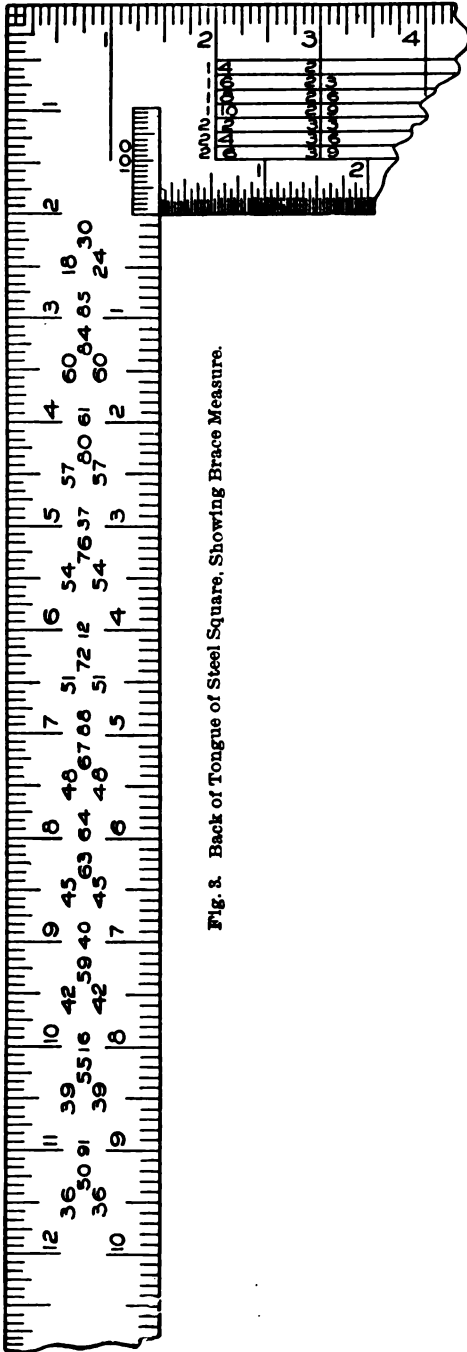
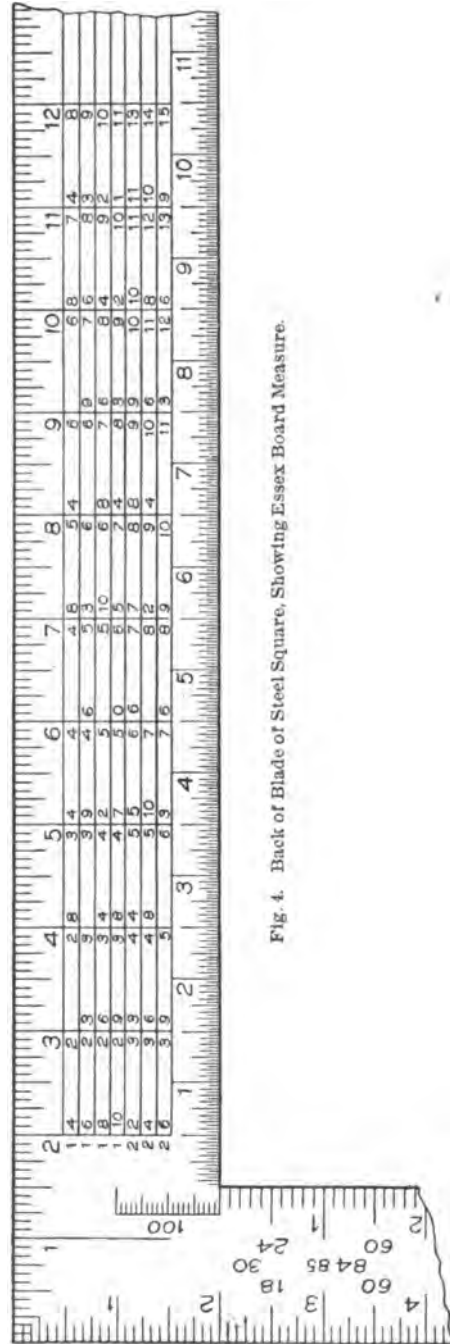


Fig. 3. Back of Tongue of Steel Square, Showing Brace Measure.



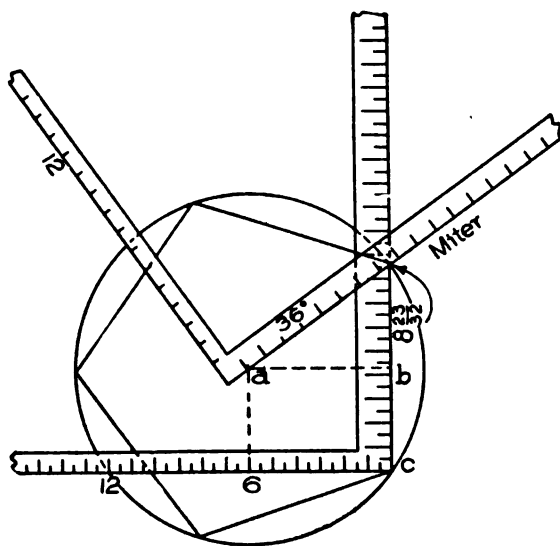


Fig. 5. Use of Steel Square to Find Miter and Side of Pentagon.

is shown a pentagon figure. The miters of the pentagon stand at 72 degrees with each other, and are found by dividing 360 by 5, the number of sides in the pentagon. But the angle when applied to the square to obtain the miter, is only one-half of 72, or 36 degrees, and intersects the blade at $8\frac{2}{3}$, as shown in Fig. 5.

By squaring up from 6 on the tongue, intersecting the degree line at *a*, the center *a* is determined either for the inscribed or the circumscribed diameter, the radii being *a b* and *a c*, respectively.

The length of the sides will be $8\frac{2}{3}$ inches to the foot.

If the length of the inscribed diameter be 8 feet, then the sides would be $8 \times 8\frac{2}{3}$ inches.

inches wide. To find the contents, look under 12, and find 14; then follow this space along to the cross-line under 9, the width of the board; and here is found 10 feet 6 inches, denoting the contents of a board 14 feet long and 9 inches wide.

To Find the Miter and Length of Side for any Polygon, with the Steel Square. In Fig. 5

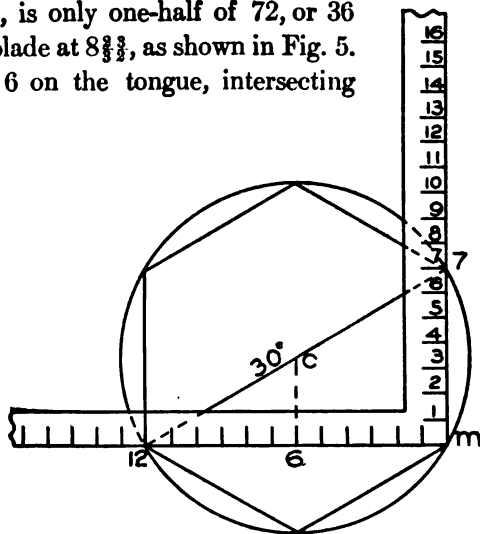


Fig. 6. Use of Steel Square to Find Miter and Side of Hexagon.

The figures to use for other polygons are as follows:

Triangle	$20\frac{3}{4}$
Square	12
Hexagon	7
Nonagon	$4\frac{3}{8}$
Decagon	$3\frac{7}{8}$

In Fig. 6 the same process is used in finding the miter and side of the hexagon polygon.

To find the degree line, 360 is divided by 6, the number of sides, as follows:

$$360 \div 6 = 60; \text{ and}$$

$$60 \div 2 = 30 \text{ degrees.}$$

Now, from 12 on tongue, draw a line making an angle of 30 degrees with the tongue. It will cut the blade in 7 as shown; and from 7 to *m*, the heel of the square, will be the length of the side. From 6 on tongue, erect a line to cut the degree line in *c*; and with *c* as center, describe a circle having the radius of *c* 7; and around the circle, complete the hexagon by taking the length 7 *m* with the compass for each side, as shown.

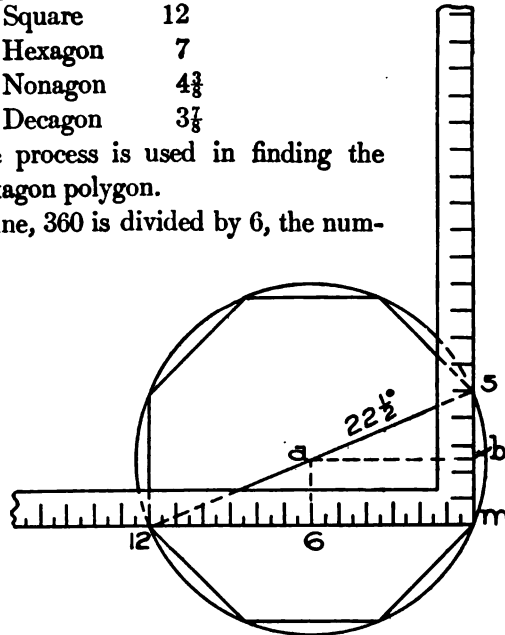


Fig. 7. Use of Steel Square to Find Miter and Side of Octagon.

In Fig. 7 the same process is shown applied to the octagon. The degree line in all the polygons is found by dividing 360 by the number of sides in the figure:

$$360 \div 8 = 45; \text{ and } 45 \div 2 = 22\frac{1}{2} \text{ degrees.}$$

This gives the degree line for the octagon. Complete the process as was described for the other polygons.

By using the following figures for the various polygons, the miter lines may be found; but in these figures no account is taken of the relative size of sides to the foot as in the figures preceding:

Triangle	7 in.	and	4 in.
Pentagon	11 "	"	8 "
Hexagon	4 "	"	7 "
Heptagon	$12\frac{1}{2}$ "	"	6 "

Octagon	17 in. and 7 in.
Nonagon	22½ " " 9 "
Decagon	9½ " " 3 "

The miter is to be drawn along the line of the first column, as shown

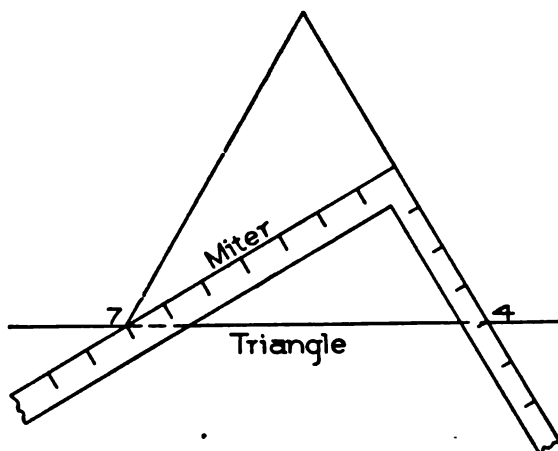


Fig. 8. Use of Square to Find Miter of Equilateral Triangle.

for the triangle in Fig. 8, and for the hexagon in Fig. 9.

In Fig. 10 is shown a diagram for finding degrees on the square. For example, if a pitch of 35 degrees is required, use $8\frac{1}{3}$ on tongue and 12 on blade; if 45 degrees, use 12 on tongue and 12 on blade; etc.

In Fig. 11 is shown the relative length of run for a rafter and a hip, the rafter being 12 inches and the hip 17 inches. The reason, as shown in this diagram, why 17 is taken for the run of the hip, instead of 12 as for the common rafter, is that the seats of the common rafter and hip do not run parallel with each other, but diverge in roofs of equal pitch at an angle of 45 degrees; therefore, 17 inches taken on the run of the hip is equal to only 12 inches when taken on that of the common rafter, as shown by the dotted line from heel to heel of the two squares in Fig. 11.

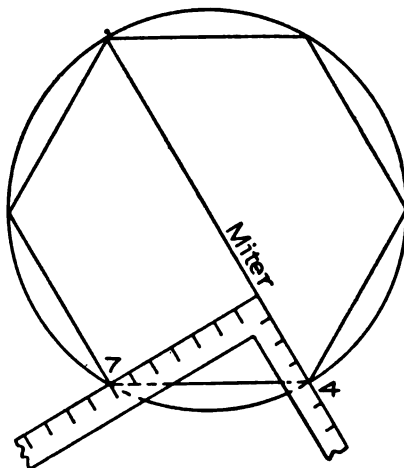


Fig. 9. Use of Square to Find Miter of Hexagon.

In Fig. 12 is shown how other figures on the square may be found for corners that deviate from the 45 degrees. It is shown that

for a pentagon, which makes a 36-degree angle with the plate, the figure to be used on the square for run is $14\frac{7}{8}$ inches; for a hexagon, which makes a 30-degree angle with the plate, the figure will be $13\frac{7}{8}$ inches; and for an octagon, which makes an angle of $22\frac{1}{2}$ degrees with the plate, the figure to use on the square for run of hip to correspond to the run of the common

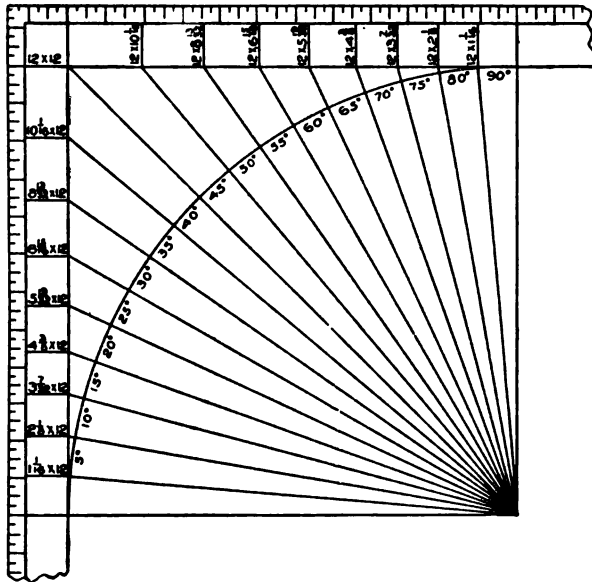


Fig. 10. Diagram for Finding Pitches of Various Degrees by Means of the Steel Square.

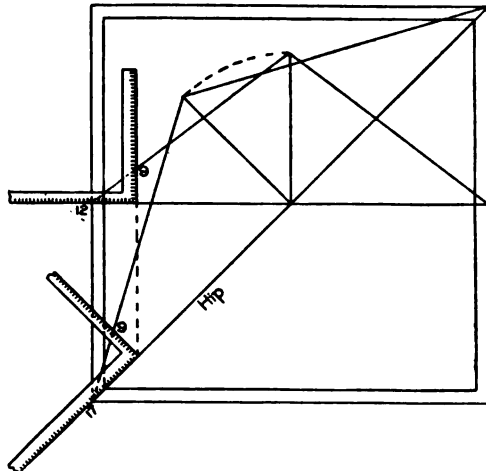


Fig. 11. Square Applied to Determine Relative Length of Run for Rafter and Hip.

rafters, will be 13 inches. It will be observed that the height in each case is 9 inches.

Fig. 13 illustrates a method of finding the relative height of a hip or valley per foot run to that of the common rafter. The square is shown placed with 12 on blade and 9 on tongue for the common rafter; and shows that for the hip the rise is only $6\frac{6}{7}$ inches.

The Steel Square as Applied in Roof Framing. Roof framing at present is as simple as it

possibly can be, so that any attempt at a new method would be super-

fluous. There may, however, be a certain way of presenting the subject that will carry with it almost the weight assigned to a new theory, making what is already simple still more simple.

The steel square is a mighty factor in roof framing, and without doubt the greatest tool in practical potency that ever was invented

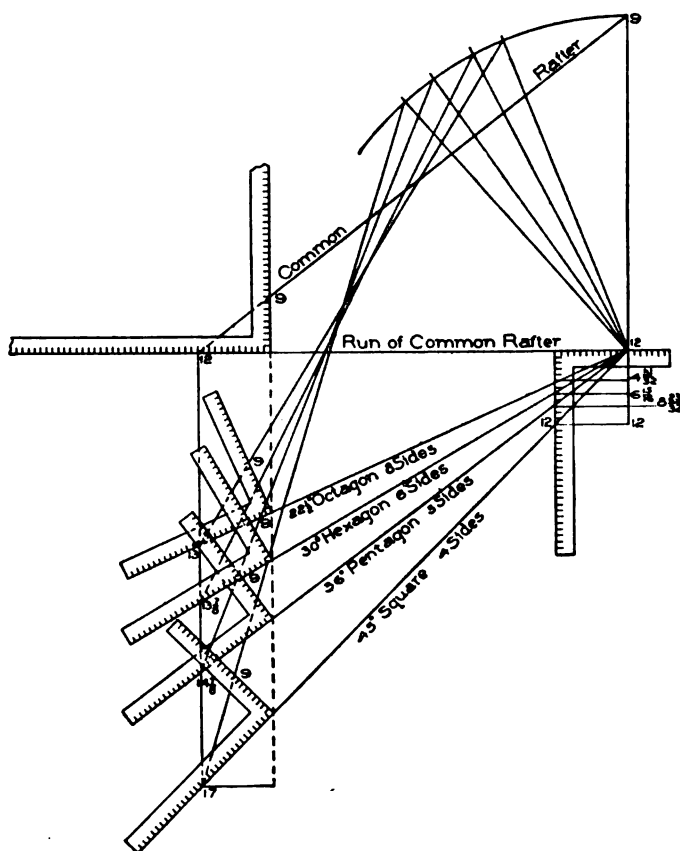


Fig. 12. Use of Square to Determine Length of Run for Rafters on Corners Other than 45°.

for the carpenter. With its use the lengths and bevels of every piece of timber that goes into the construction of the most intricate design of roof, can easily be obtained, and that with but very little knowledge of lines.

In roofs of equal pitch, as illustrated in Fig. 14, the steel square is all that is required if one properly understands how to handle it.

What is meant by a *pitch* of a roof, is the number of inches it rises to the foot of run.

In Fig. 15 is shown the steel square with figures representing

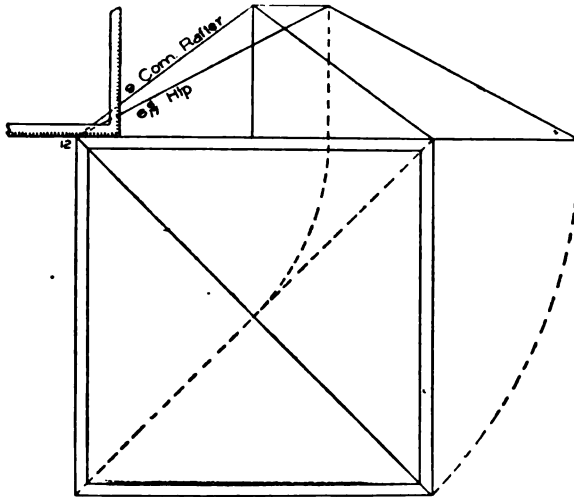


Fig. 13. Method of Finding Relative Height of Hip or Valley per Foot of Run to that of Common Rafter.

the various pitches to the foot of run. For the $\frac{1}{2}$ -pitch roof, the figures as shown, from 12 on tongue to 12 on blade, are those to be used on the steel square for the common rafter; and for $\frac{3}{4}$ pitch, the figures to be used on the square will be 12 and 9, as shown.

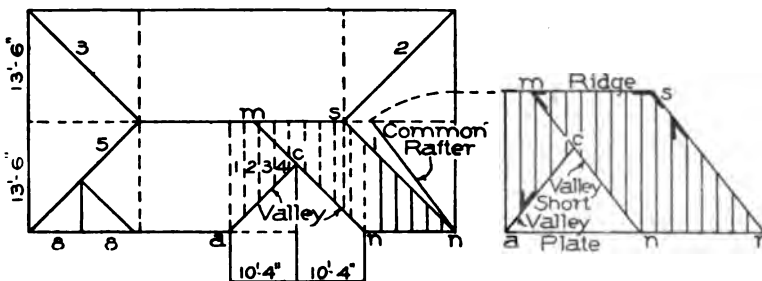


Fig. 14. Diagram to Illustrate Use of Steel Square in Laying Out Timbers of Roofs of Equal Pitch.

To understand this figure, it is necessary only to keep in mind that the pitch of a roof is reckoned from the span. Since the run in each pitch as shown is 12 inches, the span is two times 12 inches, which

equals 24 inches; hence, 12 on blade to represent the foot run, and 12 on tongue to represent the rise over $\frac{1}{2}$ the span, will be the figures on the square for a $\frac{1}{2}$ -pitch roof.

For the $\frac{3}{8}$ pitch, the figures are shown to be 12 on tongue and 9 on blade, 9 being $\frac{3}{8}$ of the span, 24 inches.

The same rule applies to all the pitches. The $\frac{1}{6}$ pitch is shown to rise 4 inches to the foot of run, because 4 inches is $\frac{1}{6}$ of the span, 24 inches, the $\frac{1}{3}$ pitch is shown to rise 8 inches to the foot of run, because 8 inches is $\frac{1}{3}$ of the span, 24 inches; etc.

The roof referred to in Figs. 16 and 17 is to rise 9 inches to the foot of run; it is therefore a $\frac{3}{8}$ -pitch roof. For all the common rafters, the figures to be used on the square will be 12 on blade to represent the run, and 9 on tongue to represent the rise to the foot of run; and for all the hips and valleys, 17 on blade to represent the run, and 9 on tongue to represent the rise of the roof to the foot of run.

Why 17 represents the run for all the hips and valleys, will be understood by examining Fig. 19, in which 17 is shown to be the diagonal of a foot square.

In equal-pitch roofs the corners are square, and the plan of the hip or valley will always be a diagonal of a square corner as shown at 1, 2, 3, and 5 in Fig. 14.

In Fig. 18 are shown $\frac{1}{6}$ pitch, $\frac{3}{8}$ pitch and $\frac{1}{2}$ pitch over a square corner.

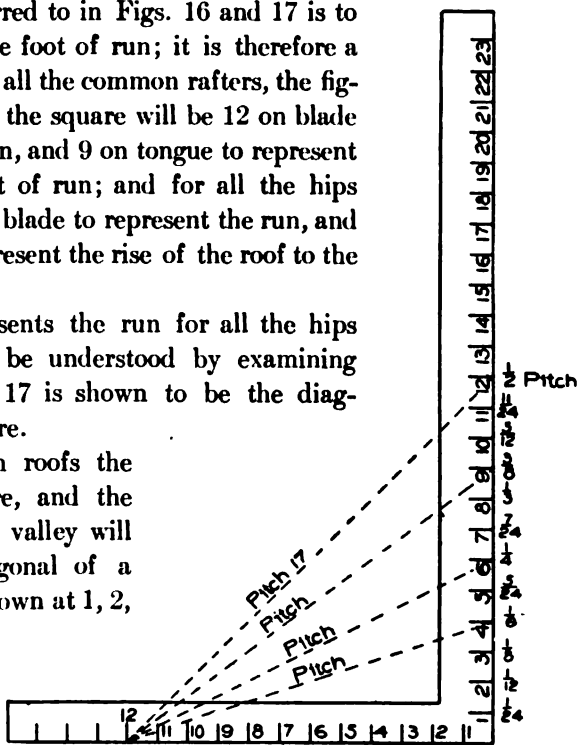


Fig. 15. Steel Square Giving Various Pitches to Foot of Run.

The figures to be used on the square for the hip, will be 17 for run in each case. For the $\frac{1}{6}$ pitch, the figures to be used would be 17 inches run and 4 inches rise, to correspond with the 12 inches run and 4 inches rise of the common rafter. For the $\frac{3}{8}$ pitch, the figures to be used for hip would be 17 inches run and 9 inches rise, to corre-

spond with the 12 inches run and 9 inches rise of the common rafter; and for the $\frac{1}{2}$ pitch, the figures to be used on the square will be 17 inches run and 12 inches rise, to correspond with the 12 inches run and 12 inches rise of the common rafter.

It will be observed from above, that in all cases where the plan of the hip or valley is a diagonal of a square, the figures to be used on

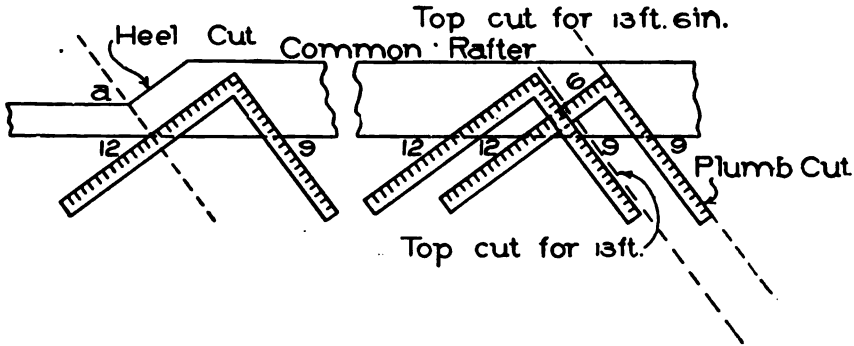


Fig. 16. Method of Laying Out Common Rafters of a $\frac{3}{4}$ -Pitch Roof.

the square for run will be 17 inches; and for the rise, whatever the roof rises to the foot of run. It should also be remembered that this is the condition in all roofs of equal pitch, where the angle of the hip or valley is a 45-degree angle, or, in other words, where we have the diagonal of a square.

It has been shown in Fig. 12 how other figures for other plan angles may be found; and that in each case the figures for run vary

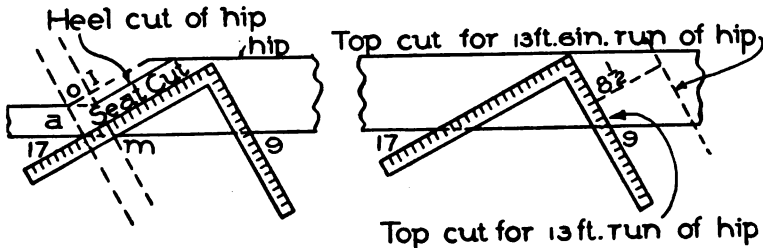


Fig. 17. Method of Laying Out Hips and Valleys of a $\frac{3}{4}$ -Pitch Roof.

according to the plan angle of the hip or valley, while the figure for the height in each case is similar.

In Fig. 14 are shown a variety of runs for common rafters, but all have the same pitch; they rise 9 inches to the foot of run. The main

roof is shown to have a span of 27 feet, which makes the run of the common rafter 13 feet 6 inches. The run of the front wing is shown to be 10 feet 4 inches; and the run of the small gable at the left corner of the front, is shown to be 8 feet.

The diversity exhibited in the runs, and especially the fractional part of a foot shown in two of them, will afford an opportunity to treat of the main difficulties in laying out roof timbers in roofs of equal pitch. Let it be determined to have a rise of 9 inches to the foot of

run; and in this connection it may be well to remember that the proportional rise to the foot run for roofs of equal pitch makes not the least difference in the method of treatment.

To lay out the common rafters for the main roof, which has a run of 13 feet 6 inches, proceed as shown in Fig. 16.

Take 12 on the blade and 9 on the tongue, and step 13 times along the rafter timber. This will give the length of rafter for 13 feet of run. In this example, however, there is another 6 inches

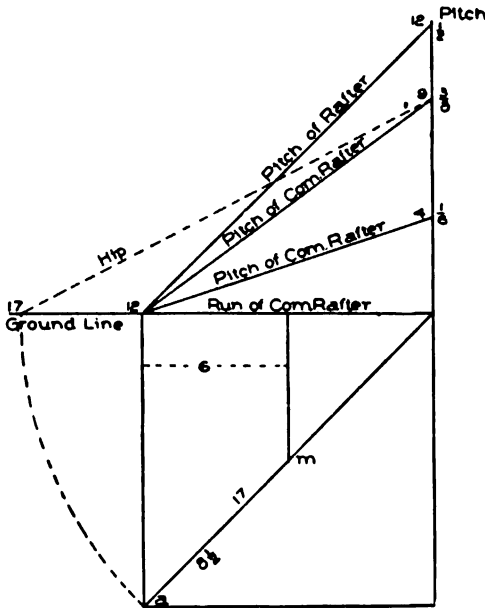


Fig. 18. Method of Laying Out Hips and Rafters for Roofs of Various Pitches over Square Corner.

of run to cover. For this additional length, take 6 inches on the blade (it being $\frac{1}{2}$ a foot run) for run, and take $\frac{1}{2}$ of 9 on the tongue (which is $4\frac{1}{2}$ inches), and step one time. This, in addition to what has already been found by stepping 13 times with 12 and 9, will give the full length of the rafter.

The square with 12 on blade and 9 on tongue will give the heel and plumb cuts.

Another method of finding the length of rafter for the 6 inches is shown in Fig. 16, where the square is shown applied to the rafter

timber for the plumb cut. Square No. 1 is shown applied with 12 on blade and 9 on tongue for the length of the 13 feet. Square from this cut, measure 6 inches, the additional inches in the run; and to this point move the square, holding it on the side of the rafter timber with 12 on blade and 9 on tongue, as for a full foot run.

It will be observed that this method is easily adapted to find any fractional part of a foot in the length of rafters.

In the front gable, Fig. 14, the fractional part of a foot is 4 inches to be added to 10 feet of run; therefore, in that case, the line shown measured to 6 inches in Fig. 16 would measure only 4 inches for the front gable.

Heel Cut of Common Rafter. In Fig. 16 is also shown a method to lay out the heel cut of a common rafter. The square is shown applied with 12 on blade and 9 on tongue; and from where the 12 on the square intersects the edge of the rafter timber, a line is drawn square to the blade as shown by the dotted line from 12 to *a*. Then the thickness of the part of the rafter that is to project beyond the plate to hold the cornice, is gauged to intersect the dotted line at *a*; and from *a*, the heel cut is drawn with the square having 12 on blade and 9 on tongue, marking along the blade for the cut.

The common rafter for the front wing, which is shown to have a run of 10 feet 4 inches, is laid out precisely the same, except that for this rafter the square with 12 on blade and 9 on tongue will have to be stepped along the rafter timber only 10 times for the 10 feet of run; and for the fractional part of a foot (4 inches) which is in the run, either of the two methods already shown for the main rafter may be used.

The proportional figures to be used on the square for the 4 inches will be 4 on blade and $2\frac{1}{2}$ on tongue; and if the second method is used, make the addition to the length of rafter for 10 feet, by drawing a line 4 inches square from the tongue of square No. 1 (see Fig. 16), instead of 6 inches as there shown for the main rafter.

Hips. Three of the hips are shown in Fig. 14 to extend from the plate to the ridge-pole; they are marked in the figure as 1, 2, and 3 respectively, and are shown in plan to be diagonals of a square measuring 13 feet 6 inches by 13 feet 6 inches; they make an angle, therefore, of 45 degrees with the plate.

In Fig. 18 it has been shown that a hip standing at an angle of 45 degrees with the plate will have a run of 17 inches for every foot run of the common rafter. Therefore, to lay out the hips, the figures on the square will be 17 for run and 9 for rise; and by stepping 13 times along the hip rafter timber, the length of hip for 13 feet of run is obtained. The length for the additional 6 inches in the run may be found by squaring a distance of $8\frac{1}{2}$ inches, as shown in Fig. 17,

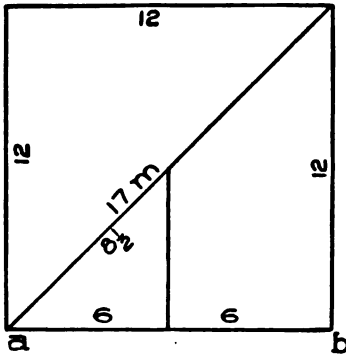


Fig. 19. Diagram Showing Relative Lengths of Run for Hips and Common Rafters in Equal-Pitch Roofs.

from the tongue of the square, and moving square No. 1 along the edge of the timber, holding the blade on 17 and tongue on 9, and marking the plumb cut where the dotted line is shown.

In Fig. 18 is shown how to find the relative run length of a portion of a hip to correspond to that of a fractional part of a foot in the length of the common rafter. From 12 inches, measure along the run of the common rafter 6 inches, and drop a line to cut the diagonal line

in *m*. From *m* to *a*, along the diagonal line, will be the relative run length of the part of hip to correspond with 6 inches run of the common rafter, and it measures $8\frac{1}{2}$ inches.

The same results may be obtained by the following method of figuring:

$$\begin{array}{r} \text{As } 12 : 17 :: 6 \\ \quad \quad 6 \\ 12 \overline{)102} \\ \underline{8} - 6 = 8\frac{1}{2} \end{array}$$

In Fig. 19 is shown a 12-inch square, the diagonal *m* being 17 inches. By drawing lines from the base *ab* to cut the diagonal line, the part of the hip to correspond to that of the common rafter will be indicated on the line 17. In this figure

it is shown that a 6-inch run on *ab*, which represents the run of a foot of a common rafter, will have a corresponding length of $8\frac{1}{2}$

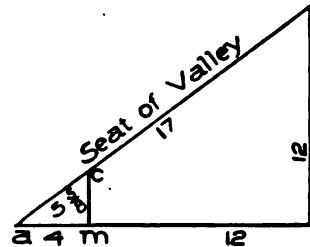


Fig. 20. Method of Determining Run of Valley for Additional Run in Common Rafter.

inches run on the line 17, which represents the plan line of the hip or valley in all equal-pitch roofs.

In the front gable, Fig. 14, it is shown that the run of the common rafter is 10 feet 4 inches. To find the length of the common rafter,

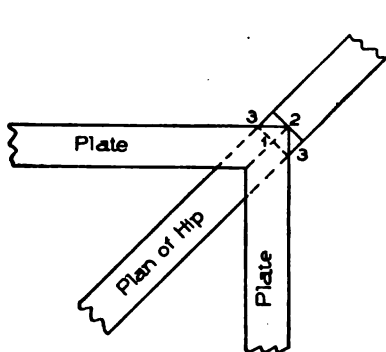


Fig. 21. Corner of Square Building, Showing Plan Lines of Plates and Hip.

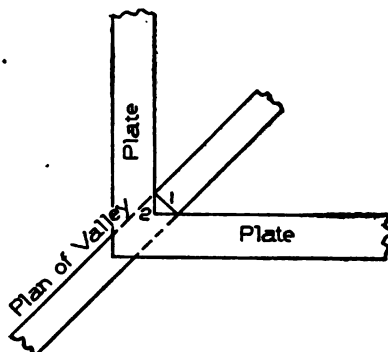


Fig. 22. Corner of Square Building, Showing Plan Lines of Plates and Valley.

take 12 on blade and 9 on tongue, and step 10 times along the rafter timber; and for the fractional part of a foot (4 inches), proceed as was shown in Fig. 16 for the rafter of the main roof; but in this case measure out square to the tongue of square No. 1, 4 inches instead of 6 inches.

The additional length for the fractional 4 inches run can also be found by taking 4 inches on blade and 3 inches on tongue of square, and stepping one time; this, in addition to the length obtained by

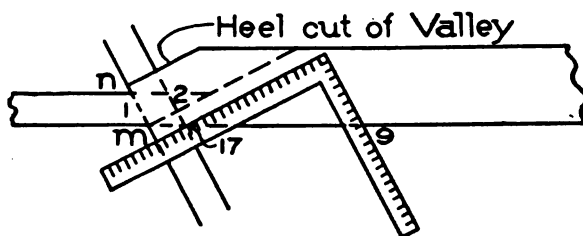


Fig. 23. Use of Square to Determine Heel Cut of Valley.

stepping 10 times along the rafter timber with 12 on blade and 9 on tongue, will give the full length of the rafter for a run of 10 feet 4 inches.

In the intersection of this roof with the main roof, there are shown to be two valleys of different lengths. The long one extends from the plate at *n* (Fig. 14) to the ridge of the main roof at *m*; it has therefore

a run of 13 feet 6 inches. For the length, proceed as for the hips, by taking 17 on blade of the square and 9 on tongue, and stepping 13 times for the length of the 13 feet; and for the fractional 6 inches, proceed precisely as shown in Fig. 17 for the hip, by squaring out from the tongue of square No. 1, $8\frac{1}{2}$ inches; this, in addition to the length obtained for the 13 feet, will give the full length of the long valley *n m*.

The length of the short valley *a c*, as shown, extends over the run of 10 feet 4 inches, and butts against the side of the long valley at *c*. By taking 17 on blade and 9 on tongue, and stepping along the rafter timber 10 times, the length for the 10 feet is found; and for the 4

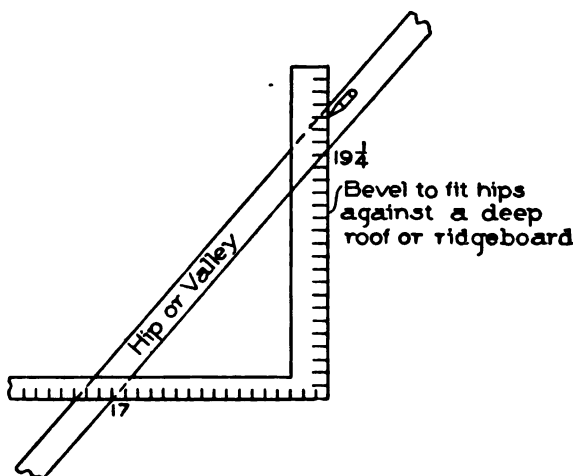


Fig. 24. Steel Square Applied to Finding Bevel for Fitting Top of Hip or Valley to Ridge.

inches, measure $5\frac{1}{2}$ inches square from the tongue of square No. 1, in the manner shown in Fig. 17, where the $8\frac{1}{2}$ inches is shown added for the 6 inches additional run of the main roof for the hips.

The length $5\frac{1}{2}$ is found as shown in Fig. 20, by measuring 4 inches from *a* to *m* along the run

of common rafter for one foot. Upon *m* erect a line to cut the seat of the valley at *c*; from *c* to *a* will be the run of the valley to correspond with 4 inches run of the common rafter, and it will measure $5\frac{1}{2}$ inches.

How to Treat the Heel Cut of Hips and Valleys. Having found the lengths of the hips and valleys to correspond to the common rafters, it will be necessary to find also the thickness of each above the plate to correspond to the thickness the common rafter will be above the plate.

In Fig. 21 is shown a corner of a square building, showing the plates and the plan lines of a hip. The length of the hip, as already found, will cover the span from the ridge to the corner 2; but the sides

of the hip intersect the plates at 3 and 3 respectively; therefore the distance from 2 to 1, as shown in this diagram, is measured backwards from *a* to 1 in the manner shown in Fig. 17; then a plumb line is drawn through 1 to *m*, parallel to the plumb cut *a*-17. From *m* to *o* on this line, measure the same thickness as that of the common rafter; and through *o* draw the heel cut to *a* as shown.

In like manner the thickness of the valley above the plate is found; but as the valley as shown in the plan figure, Fig. 22, projects beyond point 2 before it intersects the outside of the plates, the distance from 2 to 1 in the case of the valley will have to be measured outwards from 2, as shown from 2 to 1 in Fig. 23; and at the point thus found the thickness of the valley is to be measured to correspond with that of the common rafter as shown at *m n*.

In Fig. 24 is shown the steel square applied to a hip or valley timber to cut the bevel that will

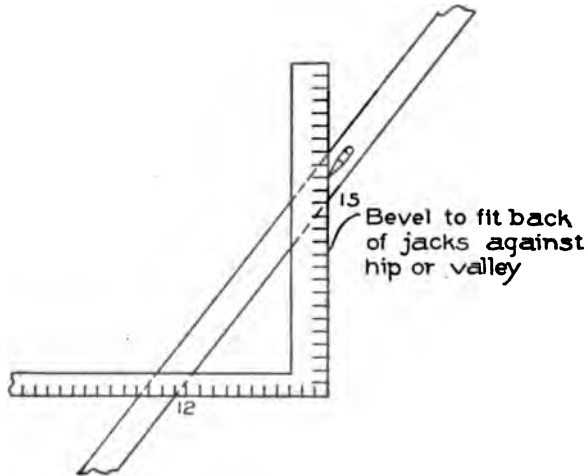


Fig. 25. Steel Square Applied to Jack Rafter to Find Bevel for Fitting against Side of Hip or Valley.

fit the top end against the ridge. The figures on the square are 17 and 19 $\frac{1}{4}$. The 17 represents the length of the plan line of the hip or valley for a foot of run, which, as was shown in previous figures, will always be 17 inches in roofs of equal pitch, where the plan lines stand at 45 degrees to the plates and square to each other.

The 19 $\frac{1}{4}$ taken on the blade represents the actual length of a hip or valley that will span over a run of 17 inches. The bevel is marked along the blade.

The cut across the back of the short valley to fit it against the side of the long valley, will be a square cut owing to the two plan lines being at right angles to each other.

In Fig. 25 is shown the steel square applied to a jack rafter to cut the back bevel, to fit it against the side of a hip or valley. The figures on the square are 12 on tongue and 15 on blade, the 12 representing a foot run of a common rafter, and the 15 the length of a rafter that will span over a foot run; marking along the blade will give the bevel.

The rule in every case to find the back bevel for jacks in roofs of equal pitch, is to take 12 on the tongue to represent the foot run, and the length of the rafter for a foot of run on the blade, marking along the blade in each case for the bevel.

In a $\frac{1}{2}$ -pitch roof, which is the most common in all parts of the country, the length of rafter for a foot of run will be 17 inches; hence it will be well to remember that 12 on tongue and 17 on blade, marking along the blade, will give the bevel to fit a jack against a hip or a valley in a $\frac{1}{2}$ -pitch roof.

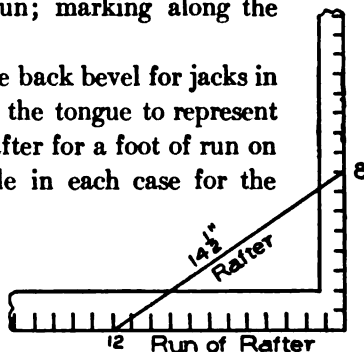


Fig. 26. Finding Length to Shorten Rafter for Jacks per Foot of Run.

In a roof having a rise of 9 inches to the foot of run, such as the one under consideration, the length of rafter for one foot of run will be 15 inches. The square as shown in Fig. 25, with 12 on tongue and 15 on blade, will give the bevel by marking along the blade.

To find the length of a rafter for a foot of run for any other pitch, place the two-foot rule diagonally from 12 on the blade of the square to the figure on tongue representing the rise of the roof to the foot of run; the rule will give the length of the rafter that will span over one foot of run.

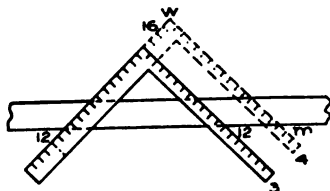


Fig. 27. Finding Length of Jack Rafter in $\frac{1}{2}$ -Pitch Roof.

The length of rafter for a foot of run will also determine the difference in lengths of jacks. For example, if a roof rises 12 inches to one foot of run, the rafter over this span has been found to be 17 inches; this, therefore, is the

number of inches each jack is shortened in one foot of run. If the rise of the roof is 8 inches to the foot of run, the length of the rafter is found for one foot of run, by placing the rule diagonally from 12 on

tongue to 8 on blade, which gives $14\frac{1}{2}$ inches, as shown in Fig. 26. This, therefore, will be the number of inches the jacks are to be shortened in a roof rising 8 inches to the foot of run. If the jacks are placed 24 inches from center to center, then multiply $14\frac{1}{2}$ by 2 = 29 inches.

In Fig. 27 is shown how to find the length with the steel square. The square is placed on the jack timber rafter with the figures that have been used to cut the common rafter. In Fig. 27, 12 on blade and 12 on tongue were the figures used to cut the common rafter, the roof being $\frac{1}{2}$ pitch, rising 12 inches to the foot of run. In the diagram it is shown how to find the length of a jack rafter if placed 16 inches from center to center. The method is to move the square as shown along the line of the blade until the blade measures 16 inches; the tongue then would be as shown from *w* to *m*, and the length of the jack would be from 12 on blade to *m* on tongue, on the edge of the jack rafter timber as shown.

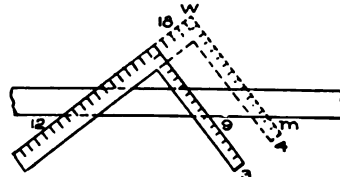


Fig. 28. Finding Length of Jack Rafter in $\frac{1}{2}$ -Pitch Roof.

This latter method becomes convenient when the space between jacks is less than 18 inches; but if used when the space is more than

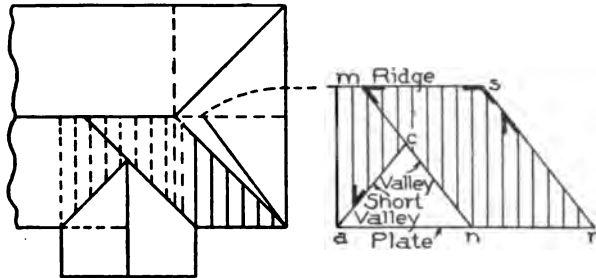


Fig. 29. Method of Determining Length of Jacks Between Hips and Valleys; also Bevels for Jacks, Hips, and Valleys.

18 inches it will become necessary to use two squares; otherwise the tongue as shown at *m* would not reach the edge of the timber.

In Fig. 28 the same method is shown for finding the length of a jack rafter for a roof rising 9 inches to the foot of run, with the jacks placed 18 inches center to center. The square in this diagram is shown placed on the jack rafter timber with 12 on blade and 9 on

tongue; then it is moved forward along the line of the blade to *w*. The blade, when in this latter position, will measure 18 inches. The tongue will meet the edge of the timber at *m*, and the distance from *m* on tongue to 12 on blade will indicate the length of a jack, or, in other words, will show the length each jack is shortened when placed

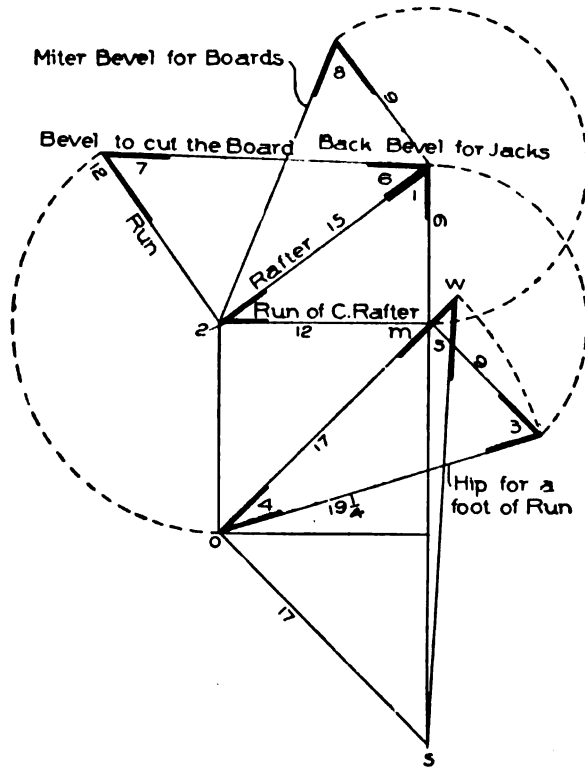


Fig. 80. Method of Finding Bevels for All Timbers in Roofs of Equal Pitch.

18 inches between centers in a roof having a pitch of 9 inches to the foot of run.

When jacks are placed between hips and valleys as shown at 1, 2, 3, 4, etc., in Fig. 14, a better method of treatment is shown in Fig. 29, where the slope of the roof is projected into the horizontal plane. The distance from the plate in this figure to the ridge *m*, equals the length of the common rafter for the main roof. On the plate *ann* is made equal to *ann* in Fig. 14. By drawing a figure like this to a scale of one inch to one foot, the length of all the jacks can be measured

and also the lengths of the hip and the two valleys. It also gives the bevels for the jacks, as well as the bevel to fit the hip and valley against the ridge; but this last bevel must be applied to the hip and valley when backed.

It has been shown before, that the figures to be used on the square for this bevel when the timber is left square on back as is the custom in construction, are the length of a foot run of a hip or valley, which is 17, on tongue, and the length of a hip or valley that will span over 17 inches run, on blade—the blade giving the bevel.

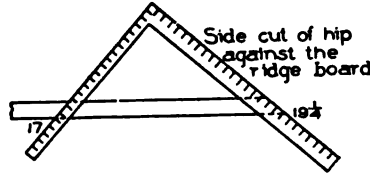


Fig. 31. Method of Finding Bevel 5, Fig. 30, for Fitting Hip or Valley Against Ridge when not Backed.

Fig. 30 contains all the bevels or cuts that have been treated upon so far, and, if correctly understood, will enable any one to frame any roof of equal pitch. In this figure it is shown that 12 inches run and 9 inches rise will give bevels 1 and 2, which are the plumb and heel cuts of rafters of a roof rising 9 inches to the foot of run. By taking these figures, therefore, on the square, 9 inches on the tongue and 12 inches on the blade, marking along the tongue will give the plumb cut, and marking along the blade will give the heel cut.

Bevels 3 and 4 are the plumb and heel cuts for the hip, and are shown to have the length of the seat of hip for one foot run, which is 17 inches. By taking 17 inches, therefore, on the blade, and 9 inches on the tongue, marking along the tongue for the plumb cut, and along

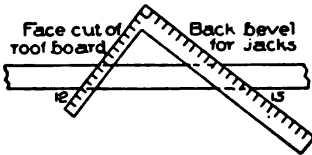


Fig. 32. Method of Finding Back Bevel 6, Fig. 30, for Jack Rafters, and Bevel 7, for Roof-Board.

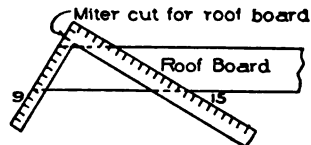


Fig. 33. Determining Miter Cut for Roof-Board.

the blade for the heel cut, the plumb and heel cuts are found. Bevel 5, which is to fit the hip or valley against the ridge when not backed, is shown from *ow*, the length of the hip for one foot of run, which is $19\frac{1}{4}$ inches, and from *os*, which always in roofs of equal pitch will be 17 inches and equal in length to the seat of a hip or valley for one foot of run.

These figures, therefore, taken on the square, $19\frac{1}{4}$ on the blade, and 17 on the tongue, will give the bevel by marking along the blade as shown in Fig. 31, where the square is shown applied to the hip timber with $19\frac{1}{4}$ on blade and 17 on tongue, the blade showing the cut.

Bevels 6 and 7 in Fig. 30 are shown formed of the length of the rafter for one foot of run, which is 15 inches, and the run of the rafter, which is 12 inches. These figures are applied on the square, as shown in Fig. 32, to a jack rafter timber; taking 15 on the blade and 12 on the tongue, marking along the blade will

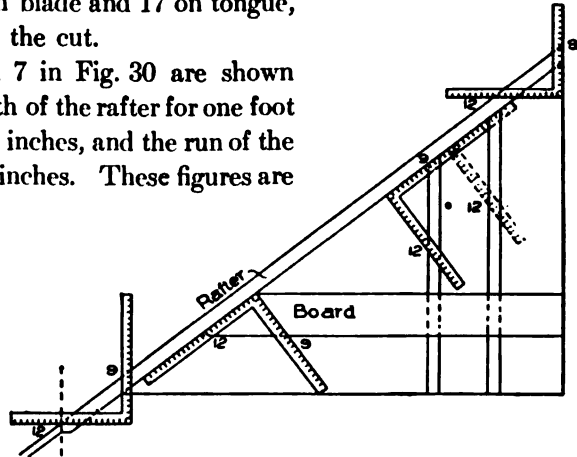


Fig. 34. Laying Out Timbers of One-half Gable of $\frac{3}{4}$ -Pitch Roof.

give the back bevel for the jack rafters, and marking along the tongue will give the face cut of roof-boards to fit along the hip or valley.

It is shown in Fig. 30, also, that by taking the length of rafter 15 inches on blade, and rise of roof 9 inches on tongue, bevel 8 will give the miter cut for the roof-boards.

In Fig. 33 the square is shown applied to a roof-board with 15 on blade, which is the length of the rafter to one foot of run, and with 9 on tongue, which is the rise of the roof to the foot run; marking along the tongue will give the miter for the boards.

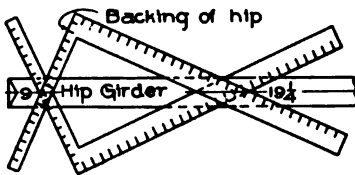
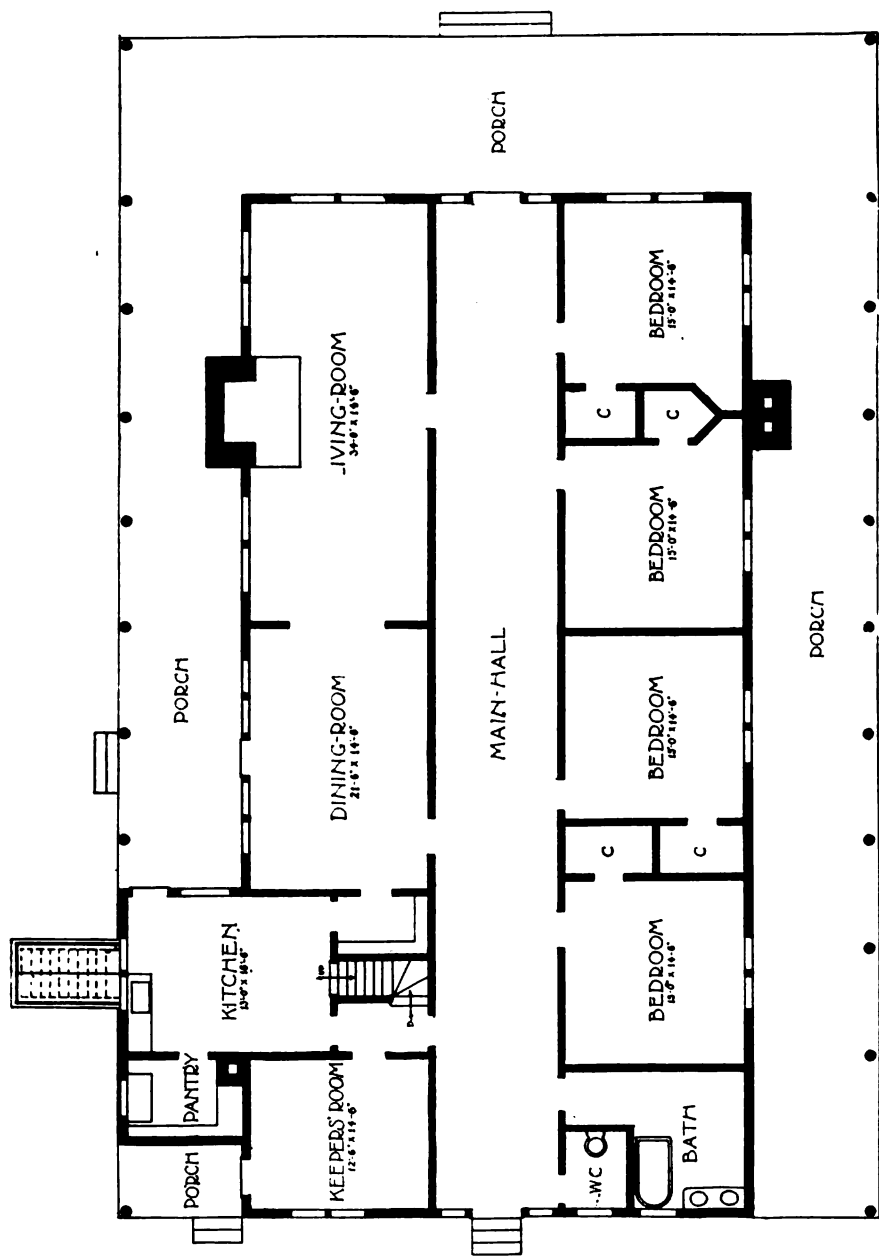


Fig. 35. Finding Backing of Hip in Gable Roof.

Other uses may be made of these figures, as shown in Fig. 34, which is one-half of a gable of a roof rising 9 inches to the foot run. The squares at the bottom and the top will give the plumb and heel cuts of the common rafter. The same

figures on the square applied to the studding, marking along the tongue for the cut, will give the bevel to fit the studding against the rafter; and by marking along the blade we obtain the cut for the boards that run across the gable. By taking $19\frac{1}{4}$ on blade, which is



PLAN OF SHOOTING LODGE FOR MR. ALBERT G. MEIER, HIGHGATE, MO.
 Dean & Dean, Architects, Chicago, Ill.



the length of the hip for one foot of run, and taking on the tongue the rise of the roof to the foot of run, which is 9 inches, and applying these as shown in Fig. 35, we obtain the backing of the hip by marking along the tongue of the two squares, as shown.

It will be observed from what has been said, that in roofs of equal pitch the figure 12 on the blade, and whatever number of inches the roof rises to the foot run on the tongue, will give the plumb and heel cuts for the common rafter; and that by taking 17 on the blade instead of 12, and taking on the tongue the figure representing the rise of the roof to the foot run, the plumb and heel cuts are found for the hips and valleys.

By taking the length of the common rafter for one foot of run on blade, and the run 12 on tongue, marking along the blade will give

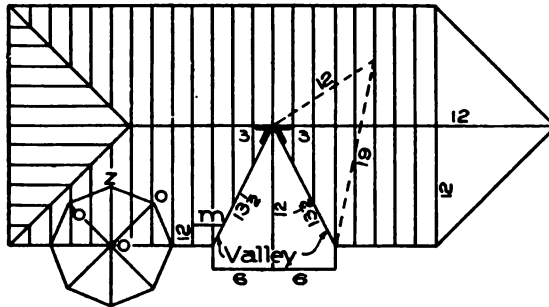


Fig. 36. Laying Out Timbers of Roof with Two Unequal Pitches.

the back bevel for the jack to fit the hip or valley, and marking along the tongue will give the bevel to cut the roof-boards to fit the line of hip or valley upon the roof.

With this knowledge of what figures to use, and why they are used, it will be an easy matter for anyone to lay out all rafters for equal-pitch roofs.

In Fig. 36 is shown a plan of a roof with two unequal pitches. The main roof is shown to have a rise of 12 inches to the foot run. The front wing is shown to have a run of 6 feet and to rise 12 feet; it has thus a pitch of 24 inches to the foot run. Therefore 12 on blade of the square and 12 on tongue will give the plumb and heel cuts for the main roof, and by stepping 12 times along the rafter timber the length of the rafter is found. The figures on the square to find the heel and

plumb cuts for the rafter in the front wing, will be 12 run and 24 rise, and by stepping 6 times (the number of feet in the run of the rafter), the length will be found over the run of 6 feet, and it will measure 13 feet 6 inches.

If, in place of stepping along the timber, the diagonal of 12 and 24 is multiplied by 6, the number of feet in the run, the length may be found even to a greater exactitude.

Many carpenters use this method of framing; and to those who have confidence in their ability to figure correctly, it is a saving of time, and, as before said, will result in a more accurate measurement; but the better and more scientific method of framing is to work to a scale of one inch, as has already been explained.

According to that method, the diagonal of a foot of run, and the number of inches to the foot run the roof is rising, measured to a scale, will give the exact length. For example, the main roof in Fig. 36 is rising 12 inches to a foot of run. The diagonal of 12 and 12 is 17 inches, which, considered as a scale of one inch to a foot, will give

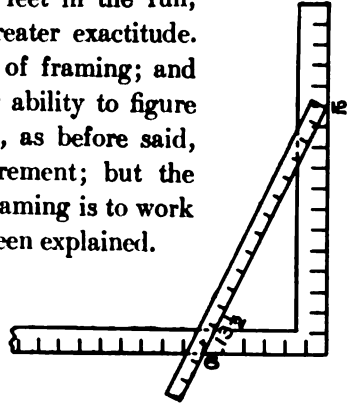


Fig. 37. Finding Length of Rafter for Front Wing in Roof Shown in Fig. 36.

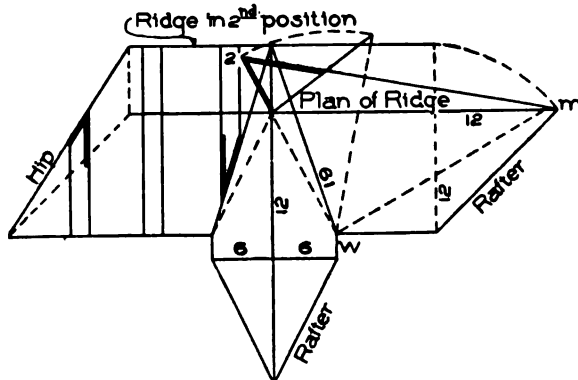


Fig. 38. Laying Out Timbers of Roof Shown in Fig. 36, by Projecting Slope of Roof into Horizontal Plane.

17 feet, and this will be the exact length of the rafter for a roof rising 12 inches to the foot run and having a run of 12 feet.

The length of the rafter for the front wing, which has a run of 6 feet and a rise of 12 feet, may be obtained by placing the rule as shown

in Fig. 37, from 6 on blade to 12 on tongue, which will give a length of 13½ inches. If the scale be considered as one inch to a foot, this will equal 13 feet 6 inches, which will be the exact length of a common rafter rising 24 inches to the foot run and having a run of 6 feet.

It will be observed that the plan lines of the valleys in this figure in respect to one another deviate from forming a right angle. In equal-pitch roofs the plan lines are always at right angles to each other, and therefore the diagonal of 12 and 12, which is 17 inches, will be the relative foot run of valleys and hips in equal-pitch roofs.

In Fig. 36 is shown how to find the figures to use on the square for valleys and hips when deviating from the right angle. A line is drawn at a distance of 12 inches from the plate and parallel to it, cutting the valley in *m* as shown. The part of the valley from *m* to the plate will measure $13\frac{1}{2}$ inches, which is the figure that is to be used on the square to obtain the length and cuts of the valleys.

It will be observed that this equals the length of the common rafter as found by the square and rule in Fig. 37. In that figure is shown 12 on tongue and 6 on blade. The 12 here represents the rise, and the 6 the run of the front roof. If the 12 be taken to represent the run of the main roof, and the 6 to represent the run of the front roof, then, the diagonal $13\frac{1}{2}$ will indicate the length of the seat of the valley for 12 feet of run, and therefore for one foot it will be $13\frac{1}{2}$ inches. Now, by taking $13\frac{1}{2}$ on the blade for run, and 12 inches on the tongue for rise, and stepping along the valley rafter timber 12 times, the length of the valley will be found. The blade will give the heel cut, and the tongue the plumb cut.

In Fig. 38 is shown the slope of the roof projected into the horizontal plane. By drawing a figure based on a scale of one inch to one

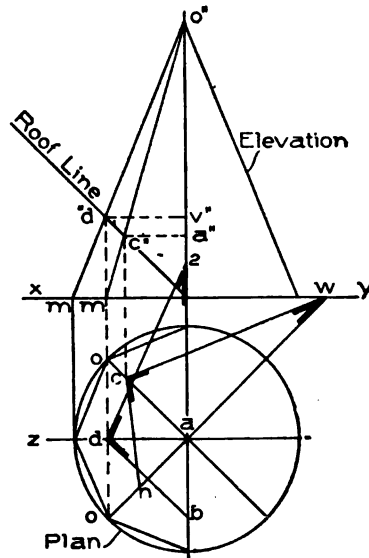


Fig. 39. Method of Finding Length and Cuts of Octagon Hips Intersecting a Roof.

foot, all the timbers on the slope of the roof can be measured. Bevel 2, shown in this figure, is to fit the valleys against the ridge. By drawing a line from w square to the seat of the valley to m , making

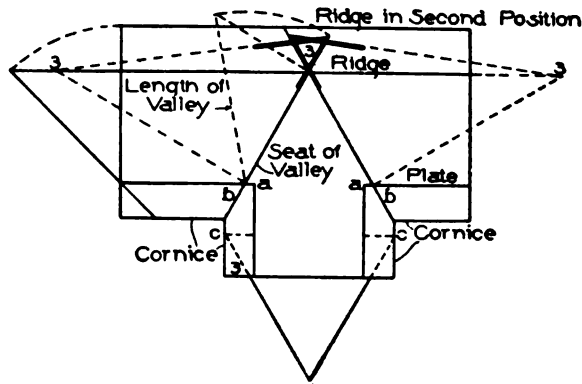


Fig. 40. Showing How Cornice Affects Valleys and Plates in Roof with Unequal Pitches.

w 2 equal in length to the length of the valley, as shown, and by connecting 2 and m , the bevel at 2 is found, which will fit the valleys against the ridge, as shown at 3 and 3 in Fig. 36.

In Fig. 39, is shown how to find the length and cuts of octagon hips intersecting a roof. In Fig. 36, half the plan of the octagon is shown to be inside of the plate, and the hips o , z , o intersect the slope of the roof. In Fig. 39, the lines below xy are the plan lines; and those

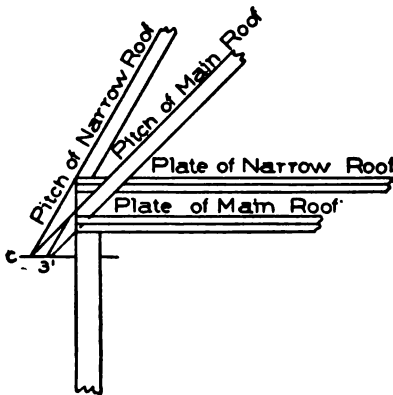


Fig. 41. Showing Relative Position of Plates in Roof with Two Unequal Pitches.

above, the elevation. From z , o , o , in the plan, draw lines to xy , as shown from o to m and from z to m ; from m and m , draw the elevation lines to the apex o'' , intersecting the line of the roof in d'' and c'' . From d'' and c'' , draw the lines $d''v''$ and $c''a''$ parallel to xy ; from c'' , drop a line to intersect the plan line ao in c . Make aw equal in length to $a''o''$ of the elevation, and connect wc ; measure from w to n the full height of the octagon as shown from xy to the apex o'' ; and connect cn . The length from w to c is that of

the two hips shown at $o o$ in Fig. 36, both being equal hips intersecting the roof at an equal distance from the plate. The bevel at w is the top bevel, and the bevel at c will fit the roof.

Again, drop a line from d'' to intersect the plan line $a z$ in d . Make $a 2$ equal to $v'' o''$ in the elevation, and connect $2 d$. Measure from 2 to b the full height of the tower as shown from $x y$ to the apex o'' in the elevation, and connect $d b$. The length $2 d$ represents the length of the hip z shown in Fig. 36; the bevel at 2 is that of the top; and the bevel at d , the one that will fit the foot of the hip to the intersecting roof.

When a cornice of any considerable width runs around a roof of this kind, it affects the plates and the angle of the valleys as shown in Fig. 40. In this figure are shown the same valleys as in Fig. 36; but, owing to the width of the cornice, the foot of each has been moved the distance $a b$ along the plate of the main roof. Why this is done is shown in the drawing to be caused by the necessity for the valleys to intersect the corners $c c$ of the cornice.

The plates are also affected as shown in Fig. 41, where the plate of the narrow roof is shown to be much higher than the plate of the main roof.

The bevels shown at 3, Fig. 40, are to fit the valleys against the ridge.

In Fig. 42 is shown a very simple method of finding the bevels for purlins in equal-pitch roofs. Draw the plan of the corner as shown, and a line from m to o ; measure from o the length $x y$, representing the common rafter, to w ; from w draw a line to m ; the bevel shown at 2 will fit the top face of the purlin. Again, from o , describe an arc to cut the seat of the valley, and continue same around to S ; connect $S m$; the bevel at 3 will be the side bevel.

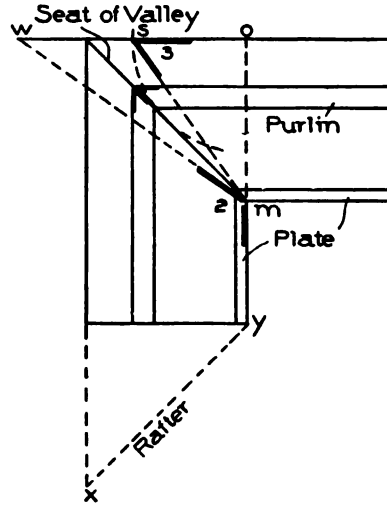


Fig. 42. Method of Finding Bevels for Purlins in Equal-Pitch Roofs.



DESIGNS FOR DOORKNOCKERS

R. Binet, Architect, Paris, France.

Reproduced from "Esquisses Décoratives de Binet, Architects."

HARDWARE

Introductory. Hardware in building is generally considered to embrace all metallic appliances of a mechanical nature. For example nails, screws binding the various parts together, hinges permitting movement, and locks to secure moving parts in place, are all in the nature of mechanical appliances. Ornamental metallic parts, such as railings, grilles, steps, etc., cannot be classed under this head.

There is no other division of building materials in which the variety is so great or the range of each variety so wide. The distance, for example, separating the cast-iron lock (Fig. 1), at one dollar and a-quarter a dozen, from the cylinder front-door lock (Fig. 2), at seventy-five dollars a dozen, is great. If, however, we were to trace the evolution from the one to the other, we should find that the extremes are connected by such fine gradations and steps that nowhere can any break in type be detected: there is no missing link.

The same conditions in varying extent apply to all other classes of hardware—hinges, bolts, etc.—and to a buyer who consults cata-

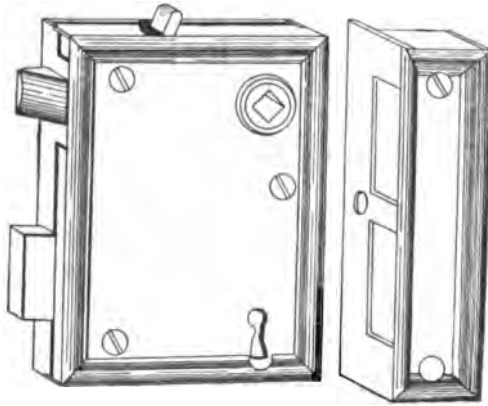


Fig. 1. Cheap Cast-Iron Lock.

logues, comes the further complication that all items are sold, not according to the *price list*, but on *discounts* from such lists. The word *discounts* is here used advisedly, for there is no one, single discount applied to all classes of hardware. For different types of appliances, there are different discounts. Some items are sold as high as 10 per cent off; the next may carry a discount of 75 per cent;

and, between these, discounts are varied and graded as delicately as are the types themselves.

Time has had a marked effect in changing the character of hardware. The latches, knockers, or locks of 150 years back are very different from any of the types characteristic of to-day; and while the imitations which can now be made are good in their way, still nowhere in the 150 years is there a marked break in the line of development from the prized antique to the best production of the present day.

As a plain example, take the nails and bolts forged in the "factory" of Jefferson at Monticello, and nearly one hundred years ago

used in the trusses over the old Senate Chamber at the Capitol in Washington (Fig. 3); compare them with those in use to-day, and then try to have duplicates forged; and the difficulty of getting the spirit of the past, even in simple things, will be appreciated.

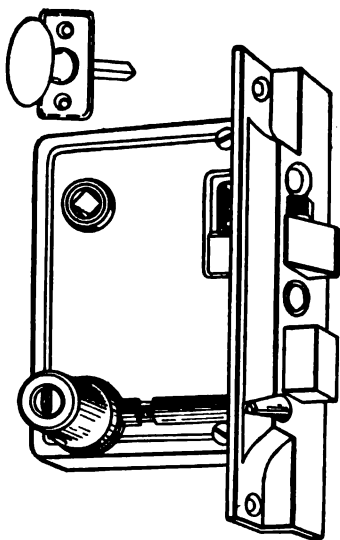


Fig. 2. Cylinder Front-Door Lock.

Nationality serves also to ring the changes. The French artisan will make a delicate but strong appliance which reflects unconsciously the influence of the objects of art with which he can and does daily come in contact. The Louvre, with its innumerable treasures of art—freely open to the street-sweeper in his blouse, as well as to the rich—has its effect on national production.

The English, from the same design, will produce something not so delicate, nor with such an artistic "go;" but it will be strong, heavy—in fact, English.

The American will make the best reproduction of the design it is possible to get from his machinery in large lots; but it often lacks the fine touch of the artist, which the French impart, or the evident firmness of purpose of the English.

Also we find the personal element exerting a strong influence. As far back as can be traced in history, different men have considered

that they possessed certain qualities, or existed under certain conditions, peculiar to themselves, which in a way distinguished them from their fellows; and they have tried to illustrate such qualities by means of insignia borne by them and put in conspicuous places in their abodes. In this way the escutcheon has always been used as a distinguishing symbol.

Comparatively little attention is paid to heraldry nowadays, especially in America. The use of the symbol on the escutcheon is, in this country, a survival of old customs now rarely seen. The name of *escutcheon*, however, still clings to what is the most con-



Fig. 8. "Jefferson" Nails and Bolts.

From Trusses of Old Senate Chamber in Capitol, Washington, D. C.

spicuous piece of house hardware now in use; and this piece of hardware tells the story of the general character of the householder who selected it, just as truly as did the escutcheon of the wandering knight of mediæval years.

It will not be the province of this paper to settle the style or kind of hardware which should be selected by people of different temperaments, or to suit any design; individual tastes and judgment must in each case govern; but it will be its province, in a general way, to point out the characteristics of the material now obtainable, the intention being to offer something more in the nature of suggestion than as an absolute guide.

NAILS AND SCREWS

These embrace the class of most uninteresting hardware—so commonplace as hardly to demand attention; but they play, after all, a large part in modern construction, and have had the greatest influence in the evolution of the now almost extinct trade of joinery, as understood a hundred years ago.

By reference to the cut of the "Jefferson" nail (Fig. 3), it will be seen that it is a wedge more adapted to splitting all wood through which it is driven than to make the parts more secure. It was the successor of the oak pin of Colonial days, and was used in much the same way. After the parts were most carefully fitted together, holes were bored only slightly smaller than the nail, and the latter was driven in to secure the close contact of the parts, which, indeed, were already fitted so nicely that they would cling together with a very slight binder.



Fig. 4. End of a Piece of Old Timber from Capitol, Washington, D. C., Showing Former Method of Making Spliced Joint.

Fig. 4 is the end of a timber taken from the Capitol, which shows how the splice joint was made; this was a *joiner's* fit, which took very little to complete the union. Through all the work of joinery—illustrated by this close fitting—the same principles extended, so that the use of nails of the Jefferson type was very limited.

Screws, except in very crude forms, were seldom used. Fig. 3 shows bolts and a nut of the same period taken from the Capitol trusses. It will be noted that in order to make their use possible, the parts must have been accurately fitted.

With modern machinery for making nails and screws, came a revolution in carpentry work. The old mortise-and-tenon timber frame gave way to the balloon frame. Joinery died a natural death, as it was found much cheaper simply to lay the pieces together and drive spikes or nails until the whole was solid. In many instances the use of spikes or nails was carried to extremes—in fact, their use became

reckless; and so important is their place in construction work, even to-day, that it is a by-word, that "any man is a carpenter who can drive a nail." But the man who can select the right nail or screw, and drive it where it is needed, and in the right way, is a rare man.

From the strictly practical standpoint, nails and screws may be divided into two classes—*First*, those used in construction work only; *second*, those used in construction work so exposed as to require consideration of the appearances they present.

For the first, round wire nails are now used almost exclusively. The older cut nail is wedge-shaped, with two rough sides, which make it hard to drive and which tear the fibre of the wood; the wedge shape, moreover, permits these nails, after they are once started, to be more easily drawn out. The wire nail is smooth, does not tear the wood, and is more easily driven than the wedge; and, on account of being of the same diameter throughout, it holds firmly even after being started in withdrawal.

A nail should never be driven clear through any woodwork so that the point appears, unless it is *clinched*, in which case a wrought-iron or "clout" nail is required; the wire nail is too hard to be easily bent and clinched. A nail driven clear through so as to expose the point unclinched will not hold so well as one shorter with the end buried.

In the frame, it is not the number of nails that tells, but their careful placing in such parts and at such points as to keep the building stiff. Nails should be grouped to afford the largest efficiency. In nailing the boarding onto a frame, for example, it is necessary to put two nails in each board to each stud. One nail would be sufficient to secure the boards; but, as there is bound to be a slight shrinkage drawing the edges of the boards apart, if the frame is not otherwise securely braced, a strong wind will rack the structure out of plumb until the edges of the boards touch again, the single nail in each board allowing a swing which would have been effectually stopped by two.

The smallest nail competent to accomplish the purpose should be used, on account of the greater ease with which it can be driven; the difference in effort required to drive ten thousand 20d nails and an equal number of 16d's is a very material item in expense.

When strength is obtained by doubling timbers and in trusses,

bolts and nuts with large washers should be used to the exclusion of nails, as a sudden jar or a slight shrinkage of the wood will prevent the nails clamping the parts closely together, and this separation or loosening of the joints materially reduces stiffness and strength.

The use of wrought-iron nails can with great profit be extended. For instance, after a house is boarded up and building paper put on, in placing the exterior finish boarding, of whatever nature it may be, if the nails are clinched on the inside, the contact will be so close as to prevent the opening of cracks between the layers, and in cold weather the nails will not "draw" and allow the joints to open.

Where nails must be used in finished surfaces, all questions of general construction must be dropped, and only such nails used as are absolutely necessary to secure the members in place; and special attention should be given to selecting nails with such heads as will not disfigure the finish. Wire nails of very small diameter and with

heads only slightly larger in size, are now made; and it is remarkable how firmly these hold the parts in place. These nails, carefully driven and with heads *set* below the surface of the finish, leave a small mark that can be readily hidden with putty colored to match the tone of the wood.

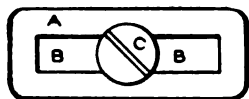


Fig. 5. Round-Head Screw with Washer.

Wherever possible, nails should be put in the quirks or concealed places, rather than in plain surfaces where the last blow of the hammer is apt to leave a round indentation in the wood. A careful carpenter in good work can place his finish so that it can be either nailed or screwed in place from the back, or the nails or screws placed so that the heads will be covered or in inconspicuous places.

In purely constructive work, screws (unless as bolts) are little used except in special finish, such as mantels and other cabinet-work put together and finished complete before being set in place.

When it is necessary to provide for the shrinking and swelling of the work, round-head screws with washers can be used. Fig. 5 illustrates such a screw, *A* being the washer; *B* a long slot, and *C* the screw; this arrangement allows movement with the screw sliding on the washer.

When it is necessary to use screws in finished surfaces, the treatment should be exactly the reverse of that governing the use of nails.

There are many forms of screws on the market, with well-formed heads, finished in lacquer, blued, or plated (it is necessary to have *some* finish to prevent rust). A variety of typical forms are shown in Fig. 6. The custom of starting screws with a hammer—in

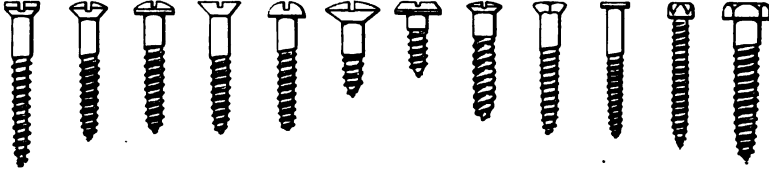


Fig. 6. Typical Forms of Screws.

fact, driving them three-quarters of the way in—should not be allowed; a screw with a battered head or not driven in straight, disfigures the work; when started by the hammer, one or both of these conditions generally prevail.

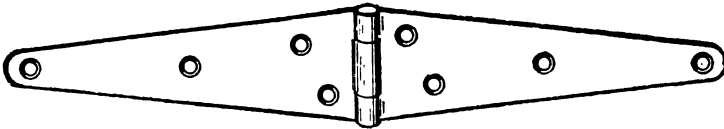


Fig. 7. Strap Hinge.

Screws which should have heads of pronounced shape, spaced regularly—in fact, made a feature in the design.

HINGES AND BUTTS

This group of hardware is the most important on the list, for

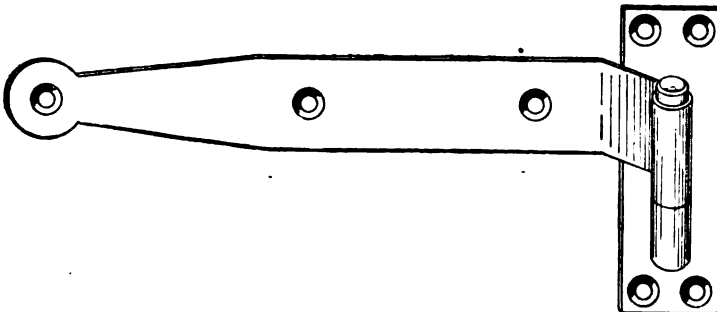


Fig. 8. Tee-Hinge with Offset.

if the hinge is out of order or lacking, the door is absolutely useless. It matters little if the latch, lock, or bolt be missing; some simple

device will supply the lock and produce the results usually obtained from the missing fixture. Without hinges, however, the door cannot be operated.

Hinges, properly speaking, consist in those appliances which are secured on the *faces* of the door and frame. Unfortunately they are now made, for the most part, in only the cheap grades, being used on barns and gates and in other inferior locations, and are known as *strap hinges* (Fig. 7) or *tee-hinges* (Fig. 8), etc.

The possibility of their artistic use is shown in the fact that manufacturers of high-grade hardware make a variety of *hinge plates* (Fig. 9) to be screwed on the face of door and frame independent of the butt, to represent the complete hinge.

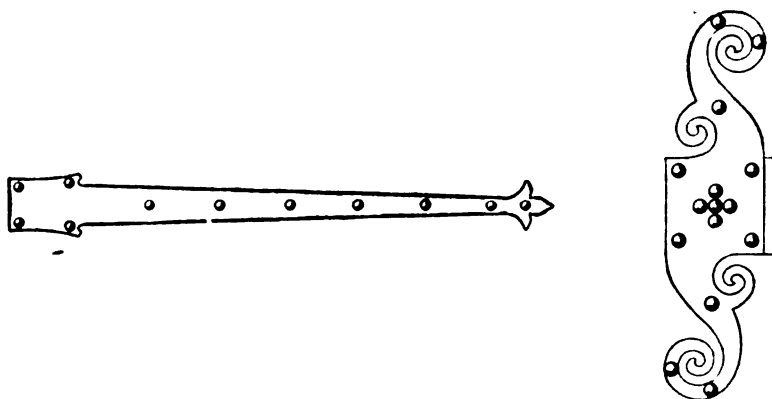


Fig. 9. Hinge Plates.

It is unfortunate that the hinge proper has dropped so completely out of the house hardware list. In its simple forms it has character and dignity. Some of the best efforts of the Gothic builders and the metal workers of the most artistic periods, have been put forth to produce hinges of perfect workmanship and design. The attempt of the manufacturers to supply the appearance by making the plates separate, has led to the production of unduly elaborated face-plates of thin metal, which are often screwed on without reference to their suitability to the location or surroundings, so that, instead of having the appearance of being a minor item for use in swinging the door, they give the impression that the door is for the special purpose of exhibiting the hardware.

The simple barn hinge may occasionally be used with propriety and good artistic effect. Fig. 10 shows a common form of the hinge on a house door where the finished timbers show throughout. These hinges are fastened by small lag-screws, and, while inexpensive, give a very artistic air to a common stock door. But there is difficulty when such appliances are used, in finding other fixtures to carry out the idea. In the case above referred to, it was necessary to have a latch forged specially (Fig. 11), as nothing suitable of stock pattern could be found.



Fig. 10. Barn Hinge Used on House Door.

The *butt* (Fig. 12) is that style of hinge (butt hinge) commonly used in swinging doors, sashes, etc., which is screwed to the butt edge of the door and which can be fully seen only when the door is open; when shut, only the knuckles of the butt are visible.



Fig. 11. Forged Latch to Accompany Hinge of Fig. 10.

Modern custom requires, in the large majority of cases, that the conventional butt be used, and it should receive the careful consideration of the designer. There are many efforts to give ornamental effects, even in the cheapest of cast-iron butts, by working patterns on the parts never seen except when the door is wide open, and by making ornamental tips on the pin which fastens them together (Fig. 13). These

attempts are unfortunate, generally serving merely to emphasize the cheap character of the article; and the plain black,

smooth surface is always to be preferred. With slight modifications, these objections may be raised against almost all attempts to make ornamental butts in other materials.

Door Butts (and this is, so far, the largest class) are made of cast iron, wrought iron, brass, or bronze, the expense increasing in that order. The cast-iron door butt should be avoided if possible, on account of its brittleness allowing it to break under slight stress, when the door, in falling, often does damage which costs more to repair than would a very expensive butt at the beginning.

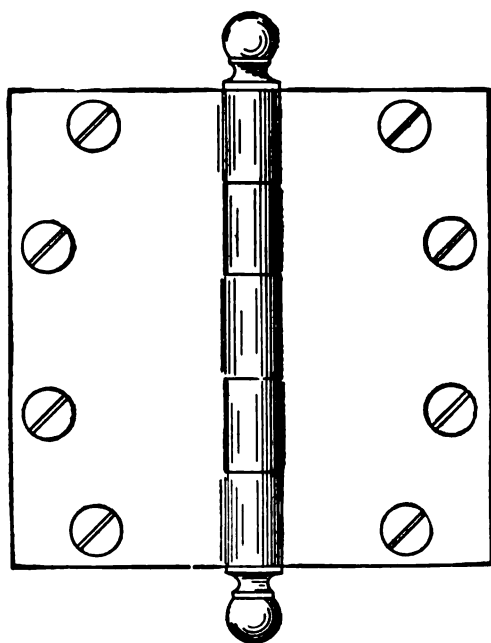
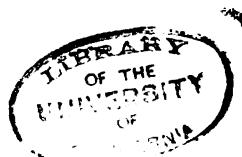


Fig. 12. Plain Butt, Loose-Pin Type.

Fig. 14 shows the ordinary type of a *five-knuckled loose-pin wrought-steel butt*. The knuckles are marked A.

If the door is hung to the wing *E*, it is evident that the bearing points of the butt will be at *B*, *B*; if the door is hung on the wing marked *F*, the bearing points will be *C*, *C*. *D* is the head of the *loose pin*, which extends through the knuckles, as indicated by dotted lines; this can be withdrawn when it is desired to take down the door.

For ordinary doors the butt should not be less than four inches high, with five knuckles to each butt for the loose-pin type. An examination will show that there are always two bearings on each five-knuckled butt, so that if there are three butts to a door there are always six bearing points; and when the weight of the door is considered, with the fact that all this weight is carried from one side, the necessity for ample bearings will be appreciated. The loose pin allows the doors to be taken down readily; and when, from excessive use, the bearings have become worn, it also allows the placing of steel



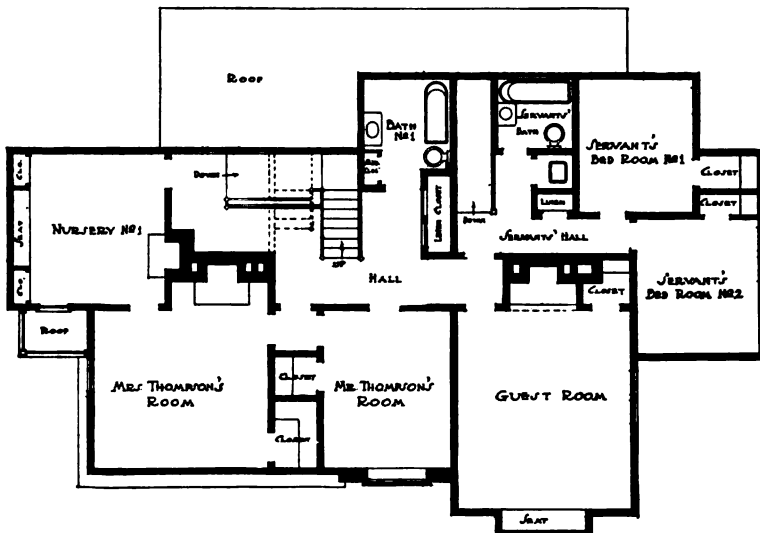
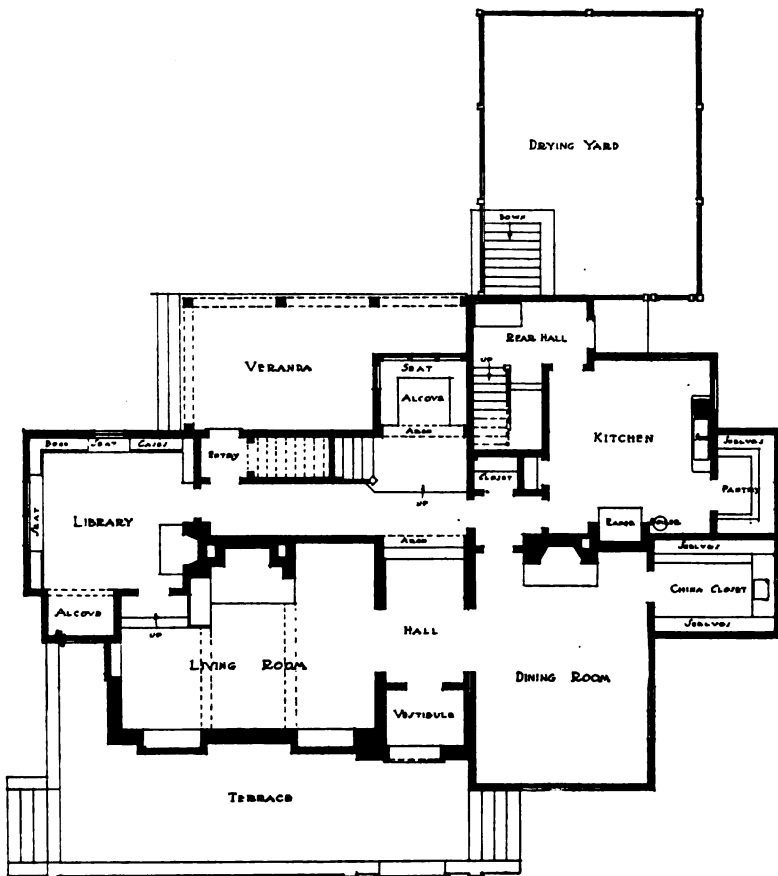


HOUSE FOR MR. C. M. THOMPSON, CAMBRIDGE, MASS.

Cram, Goodhue & Ferguson, Architects, Boston and New York

The Seven General Contract Estimates Ran from \$18,715 down to \$11,700. The House was Built at the Latter Figure, plus a Great Many Extras Added by the Owner; and to this Amount was Added \$2,000 for Plumbing and Heating. It was Built in 1900. The House Faces about South.

For Interiors, See Pages 122, 123, and 124.



**FIRST AND SECOND STORY PLANS OF HOUSE FOR
MR. C. M. THOMPSON, CAMBRIDGE, MASS.**
Cram, Goodhue & Ferguson, Architects, Boston and New York.



washers (Fig. 15) between the knuckles, to take up the worn portions.

Wrought-steel butts can be had in plain material and fair workmanship, 4 by 4 inches, as low as \$1.30 a dozen pairs, with screws; and from that up to \$7.00 a dozen fitted with ball bearings and bronze-plated. The best grade of what is commonly known as the *Stanley* butt is a good example of this type. Butts are now often

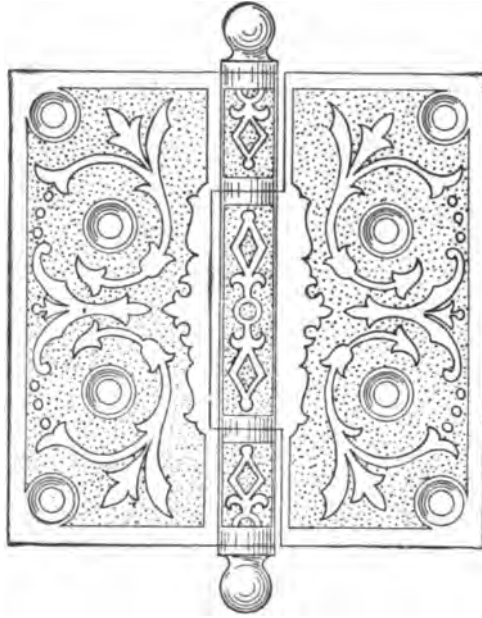


Fig. 13. Ornamental Cast-Iron Butt, Loose-Pin Type.

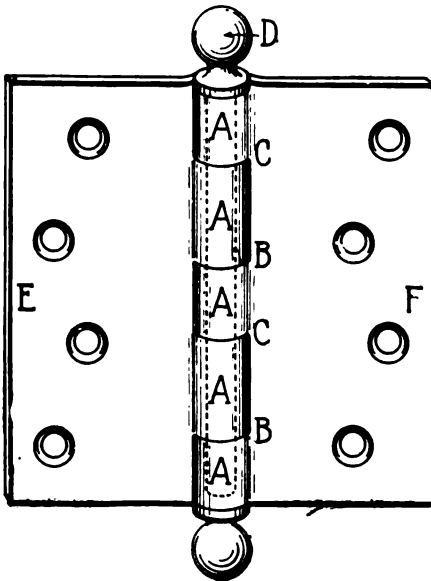


Fig. 14. Common Five-Knuckled Loose-Pin Butt.

made with ball bearings (Fig. 16), which greatly improve the wearing qualities.

Wrought-iron butts are also finished in various ways (especially in *Bower Barff*, to which finish reference is made later), and in fact can be combined with almost any line of hardware finish. They are to be recommended on account of their mechanical perfection.

Cast brass or bronze is used in expensive work, but to be efficient must be *very heavy*. The material is softer than iron; and if the bearing parts are not protected, they wear rapidly; a drop of one thirty-second of an inch in the

door on account of such wear, will at once cause inconvenience.

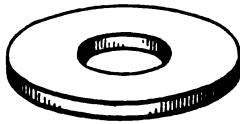


Fig. 15. Steel Washer for Butt.

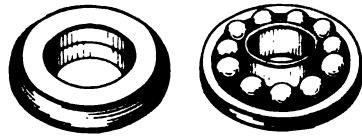


Fig. 16. Ball Bearings for Butt.

The protection against wearing of the knuckles may be by ball bearings, as above shown (Fig. 16), or, as in the more general practice, by *bushings* consisting of thin steel plates (as shown by the stippled part in Fig. 17) set in each face of each knuckle so that they receive all the wear and relieve the softer metal. In these plates are slight indentations (not stippled) which hold oil for an indefinite period. This oil lubricates the bearings. Often the knuckles are bored out, and a steel

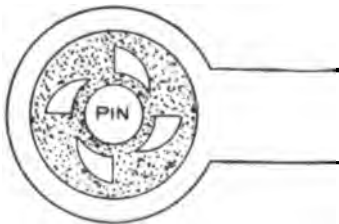


Fig. 17. Steel Plate Bushing Used between Butt Knuckles.

cylinder inserted as a bushing.

When it is advisable to use real bronze for butts, expense should not be spared to get the best from a mechanical standpoint. It is always a safe rule to get the cheaper material with perfect workmanship, rather than expensive material of indifferent workmanship.

There are many "ornamental" brass and bronze butts made by casting designs on the

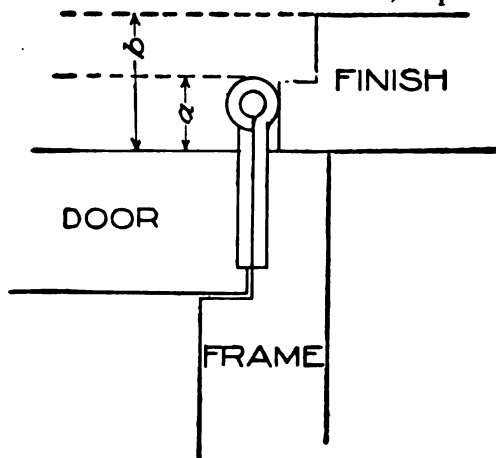


Fig. 18. Showing Necessity for Projection of Door Butt surface and emphasizing the effect by polishing the raised parts.

This does not add to the distinctness of the design, and only leaves the impression of a "well-broken" surface. *It will be noted that, in general, the plainer the butt, the higher the price, and the highest grades of butts are rarely of the ornamental variety.*

There is little ornamental value in the knuckles of a butt. A butt should, therefore, be of such a size as to project as little as possible beyond the door or frame. The only point to be carefully seen to, is that it shall extend outward far enough to throw the door clear of the trim or woodwork at the side. Thus the projection at *a*, Fig. 18, should be a trifle more than one-half the distance *b*, in order to carry the door, when opened back, clear of the side trim.

After the decision relative to the *style* of hinges or butts to be used is made, the closest attention should be given to the *mechanism*. A door in common use will wear its hinges with astonishing rapidity. Three hinges should always be used on a door. The third hinge, or the one at half the height, keeps the door from springing, and relieves the strain on the other two, so that the door is more easily operated; and it also gives 50 per cent additional wearing resistance.

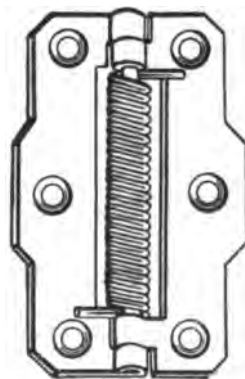


Fig. 19. Cheap Type of Spring Butt.

The same reason for using loose-pin butts as above given for doors, apply to the hanging of all items swinging on upright bearings—such as cupboard doors, window-sash, etc.; and it is sometimes necessary to use much care in the selection, in order that the swinging parts may turn clear of all obstructions or fold back on themselves, as with inside blinds.

Where the swing is from horizontal bearings, the pins should always be *fixed*—that is, so made that they cannot be removed. In an upright position gravity holds them in place; but when put horizontally, the swinging of the sash works the pin loose, and in time it is apt to fall out and allow the sash to drop, this being the case particularly in swinging transom sash.

Besides the types of butts above referred to, there are many

appliances properly classed under this head designed for special service, such as *spring butts* and *double-acting butts*.

Spring Butts. Spring butts are those in which a spring is placed so as to force the door closed when not held open by some other force. These vary from the light type commonly used on wire-screen doors,

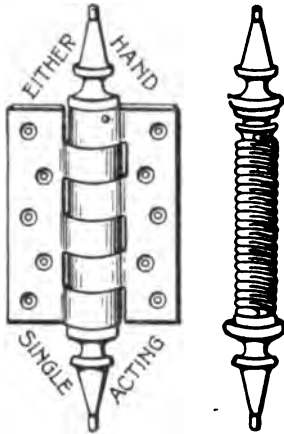


Fig. 20. Heavy Bronze Spring Butt.

costing from 10 to 15 cents a pair (Fig. 19), to heavy bronze butts with a high-grade metal spring in the joint, costing \$5.00 a pair (Fig. 20), which can be regulated to give either a strong or a light reaction.

The disadvantages of this type are that they rack the door by constant slamming; they are much more expensive than butts of the same material without the spring; and when once installed, it is practically impossible to throw the spring out of service. For the light and cheaper work, a single spiral spring (Fig. 21), costing from 15 to 25 cents, can be used independently of the butt; it is easily unhooked when not needed.

For the better grades of work and heavier doors, a spring check should be used (such as is described under *Miscellaneous Hardware*), which will close the door promptly and prevent slamming.

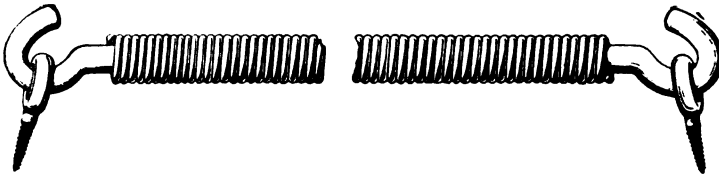


Fig. 21. Common Type of Spiral Spring for Doors.

Double-Acting Butts. The function of the double-acting butt is to allow the door to swing to both sides of the jamb. It is necessarily of the spring-butt type, above mentioned, but is double and is so set as to leave the door shut when at rest. There are no cheap types of this butt on the market, and the work required makes the best mechanism necessary. There are no appliances which can be sub-

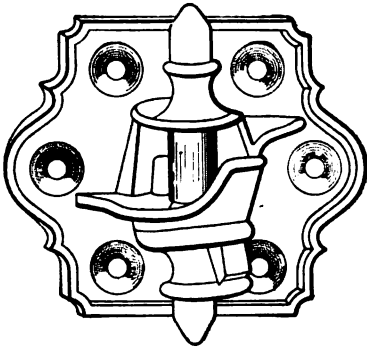


Fig. 22. Gravity Blind Hinge.

In selecting double-acting butts, always get a large size capable of doing the work easily, as the jar on a light butt as the door passes the closed point will quickly rack a light appliance into a useless condition. In house building, the use of double-acting springs is usually confined to china-closet doors, and in public buildings to entrance doors. In a very large number of cases a little study will devise means of substituting simpler appliances. For a public building, for example, two single-acting doors can be used—one for entering and the other for outgoing traffic.

Blind Hinges. Outside *blind hinges* are important items, especially in rural districts in the North and

stituted as in the case of simple single-spring hinges. In order to do the work satisfactorily, a very large hinge is required—too large to be ornamental—so that certain types are embedded in the floor, out of sight; these are peculiarly adapted to heavy doors when the floors are of Mosaic so that the hinge can be firmly bedded in concrete.

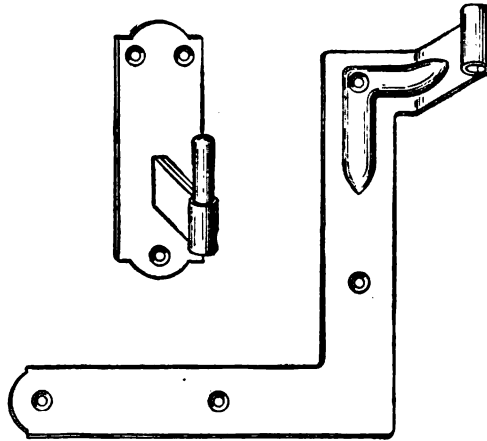


Fig. 23. Wrought-Iron Blind Hinge.

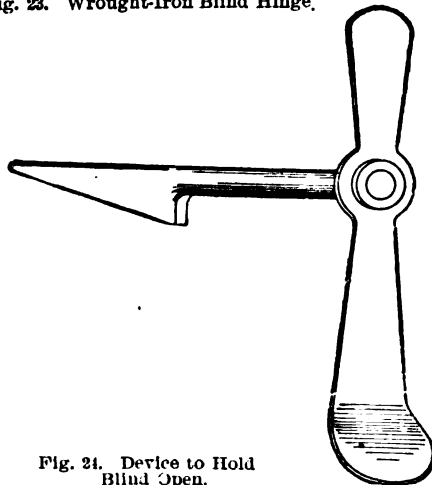


Fig. 24. Device to Hold Blind Open.

throughout the South, where blinds are a necessity. {The usual cast-iron *gravity blind hinge* (Fig. 22) is a very cheap and unsatisfactory fixture. The smallest jar or blow will break hinges of

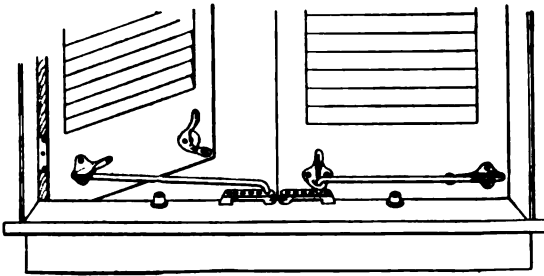


Fig. 25. Blind Adjuster.

this type. A heavy wind, catching the blind, will often slam it with sufficient force to break the window glass. It is much better to procure some type of wrought-iron hinge (Fig. 23),

and a separate appliance to hold the blind open (Fig. 24). This type of hinge is also rather ornamental, the part fastened to the face of the blind being in the true sense of the term a hinge-plate.

A *blind adjuster* is indicated in Fig. 25. There are several appliances on the market which accomplish the same result—that is, holding the blinds secure at any angle up to about 60° from the sash plane. It is very desirable to install these fixtures—which are strong, and which hold the blind firmly—where blinds with fixed slats rather than



Fig. 26. Awning Blind Hinge in Use.

rolling slats are used. If a substantial blind is desired, the fixed slats should always be used; the light passing blinds opened only two or three inches is very agreeable.

There is also on the market an *awning blind hinge*. This permits the blinds to swing in the usual way, and, in addition, to be clamped together; and with the tops against the house, the bottom can be set out from one to two feet like an awning (Fig. 26), giving a delightful soft light inside. But to accomplish all that is desired, it appears to be necessary to make these hinges delicate and light; and a little hard usage or a heavy wind will break them, so that the greatest care must always be exercised when operating these blinds, to leave them secure; and generally it may be said that such fixtures are unsuitable for wide or heavy blinds.

LOCKS

As has been stated, the hinge is the most important item of hardware from the standpoint of necessity or convenience; but it is apparently the general sentiment of both sellers and buyers, that the lock is the central figure. The manufacturer puts more thought on it than on any other appliance; and in selecting hardware, the customer generally devotes most of his attention to it. Perhaps the reason for this discrimination is that the lock symbolizes protection and defense; the term *symbolize* is here used because, on an analysis, the lock is rather a symbol than a real physical protection.

With the advancement in the art of lock-making, the knowledge of methods of nullifying the safeguard afforded by locks has also advanced, so that there are no locks to-day which cannot with more or less ease be operated by unauthorized persons. When elaborate and intricate locks are used, it is often ridiculous to see on what flimsy doors they are placed, and also what delicate and flimsy locks are placed on ponderous doors.

A brief study of the conditions usually surrounding the placing of locks will show the absurdity of expending large sums of money and of buying intricate locks with an idea of obtaining protection thereby. Under ordinary conditions, the moral effect of the lock is enough to afford protection; but when the experienced cracksman or determined burglar seeks to obtain entrance, neither moral effects nor mechanical appliances are a bar.

The object of the foregoing is to set forth the province which a lock should be considered as filling—or rather to show the province it does not fill—so that in buying this most expensive of hardware,

funds needed elsewhere may not be expended in intricate mechanism of doubtful protective value.

Locks are either of the *rim* type or of the *mortise* type. The rim lock is fastened on the face of the door (Fig. 27). It should be used only when protection is desired from the outside, as, for instance, on store or office entrance doors, and possibly outside house-doors. Locks of this type are usually operated by means of a key from the outside and a thumb-piece from the inside; if of a type requiring a key for both sides, they are no protection on the side on which they are visible, as the removal of one screw will usually allow of sufficient change of position of the lock to release the bolt.

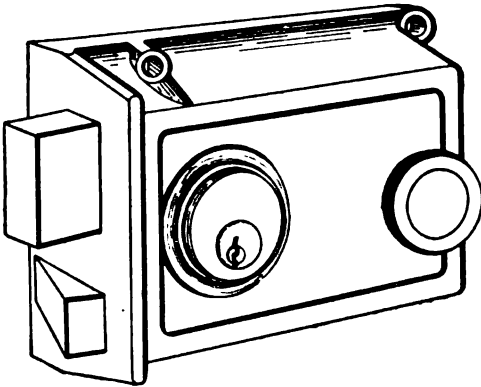


Fig. 27. Rim Lock.

Rim locks are not ornamental, are generally made of ordinary cast-iron, and their use should be avoided in the better grades of work.

The mortise lock is set into the face of the door, so that only the face-plate, with bolt and latch, shows on the edge when open (Fig. 28).

Inasmuch as it is necessary to cut out the woodwork of the door to place a lock of this type, the first consideration in its selection should be one of size. The smallest and thinnest lock which will serve the purpose should be chosen.

As all the parts except the face-plate are hidden in the mortise, there is no use in ornamental work. The exposed face is usually plain brass or bronze; the case is generally cast iron or pressed steel, which should be heavy enough to hold its shape firmly, without springing or cracking if for any reason the mortise for which it is intended is not of the proper shape or size, which it rarely is.

After the question as to the use of a rim or a mortise lock is settled, another, covering just what is wanted of each lock, should be carefully considered, so that appliances will not be installed which are never to be used. Practically all locks contain a *latch*—that is,

the part which is operated by the knobs and which holds the door closed under ordinary conditions. As the latch is the part subject to most frequent use, it is very desirable that its mechanism be as simple as possible and that all moving parts be of brass or bronze. The use of iron, except in the casing, should be avoided.

It is often observed, in finished work, that the latch is not easily pushed back when the door is shut, making it necessary to turn the knob or to give more than an ordinary slam to latch the door. This is caused by badly fitting parts, poor springs, and the shape of the latch-face. If the latter is a simple line as illustrated in Fig. 29, it will probably cause constant annoyance. If, however, the latch-face is carefully shaped after the manner shown in Fig. 30, there will be less, if any, trouble.

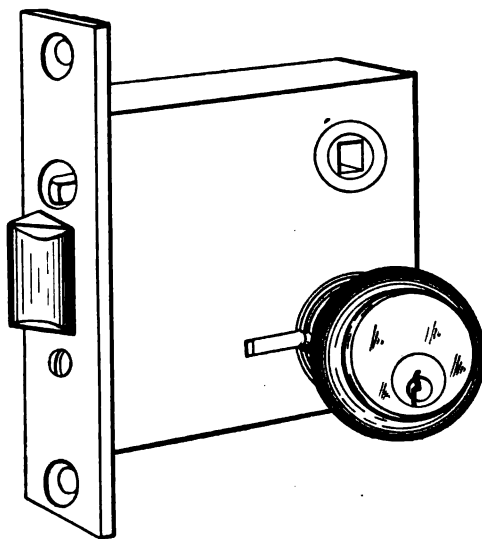


Fig. 28. Mortise Lock.

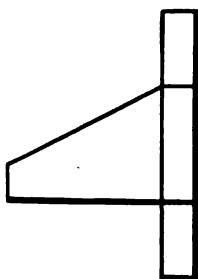


Fig. 29. Unsatisfactory Outline for Latch Face.

The latch should be heavy. It receives hard usage, and the heavier it is, the more evenly it responds to pressure. There are various *anti-friction* devices on the market, but they are rarely any improvement over the well-designed and well-manufactured latch-face. Should the selection, however, be unfortunate, and the operation of the latch unsatisfactory, conditions can be remedied to a certain extent by occasionally oiling the face of the strike with a heavy oil which will not readily disappear.

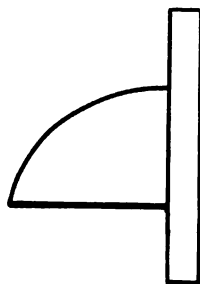


Fig. 30. Better Outline for Latch Face.

In a large majority of cases, this latch (Fig. 28) will perform all the necessary functions of the lock and latch for outside doors if it is arranged with *stopwork* on the face. By pushing in one button, it can be operated from the outside only by means of a key; by reversing the button, it becomes a latch operated by knobs from both sides. Under the former condition it is as secure a lock as is the

dead bolt operated by a key independent of the latch—a device which, while often considered a necessity for outside doors, is rarely used.

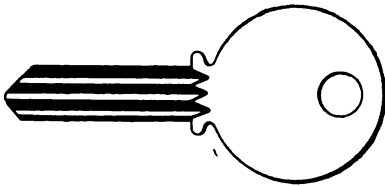


Fig. 31. Latch-Key of Flat-Key Type.

Inside doors rarely require a lock; and where they are not really needed, it is not wise to

arrange for a possible future need, since in most cases, if such need arises, the keys will either have been lost or have become hopelessly mixed.

In selecting door locks, the first and most important consideration should be given to the latch lock. A type with the heaviest mechanism and best materials in the smallest case, should be selected; and that type, in one of its various forms, should be used throughout to the exclusion of all other forms, unless unusual conditions require other appliances—as, for example, where doors are to be locked from both sides, in which case the dead bolt is necessary, which can be operated only by key from either side. With this, as with all hardware, the simplest form is the best. Locks which have peculiar combinations, such as turning the key

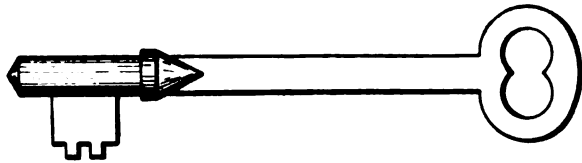


Fig. 32. Common Type of Bit Key.

in a certain way to operate one bolt, and further in the same way or in an opposite direction to operate the second bolt, are to be avoided. They afford no additional protection, and are often confusing in the extreme to the owner. The distance between the center of the knob and the face of the lock should never be less than 2½ inches, and it is better to be 3 inches. If less, the fingers of

the operator will be pinched between the knob and the door-frame.

The key is an important item, and selection of the style of key should always be with strict reference to the use of the lock. The *latch-key* will be in daily use and carried by several persons, and should be of the smallest *flat-key* type (Fig. 31), with a distinctively shaped hand end so that it can readily be distinguished at all times from desk or drawer keys on the same ring.

If a dead bolt is used, its key should be of the larger type of *bit key* (Fig. 32). This is inconvenient to carry away, is not easily lost, and can generally be found at the rare intervals when it is needed.

All keys should be strong, whether flat or bit. Delicate keys are often twisted off when the lock "sticks" a trifle, or—which happens more frequently—when they are not inserted quite far enough before an impatient wrench is given them. Once bent, they are useless. They should be well finished and nickel-plated. Otherwise they will rapidly wear the pocket, and become rusted; and a rusty key will rarely work satisfactorily.

It is often desired that locks be master-keyed—that is, so constructed that each lock will be operated by a key differing from any other, but also so made that one *master key* can open all, as in the case of office buildings, for janitors' use, and in hotels to accommodate the service. This requirement is always unfortunate, as it permits the passage of every lock in the series by one key. This is like very securely guarding several entrances to an enclosure and leaving one gate with but little protection; and it is much better to cause the janitor a little additional trouble by requiring him to carry a separate key for each lock. If the master key is lost, the only remedy is to change the entire line of locks.

There should be no identifying marks on keys or rings indicating the location of the locks they will operate, for, in case of loss, the finder would thus be enabled to use them.

In selecting locks for any particular building, a careful diagram or floor-plan should be prepared, on which the swing of all doors is indicated and each door numbered (see Fig. 33). A *right-hand* (R. H.) door is one which when opened away from a person has its butts on the right-hand jamb; and a *left-hand* (L. H.) door has its butts on the left-hand jamb. All latches are either R. H. or L. H..

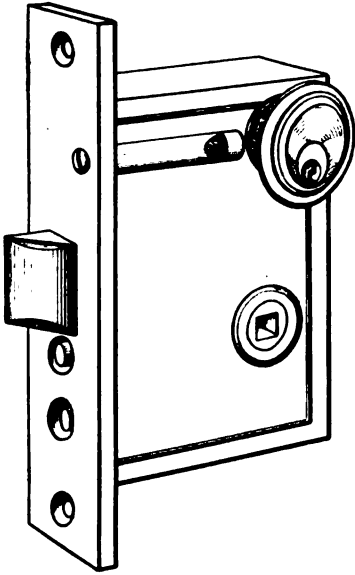


Fig. 34. Lock with Pass Key.

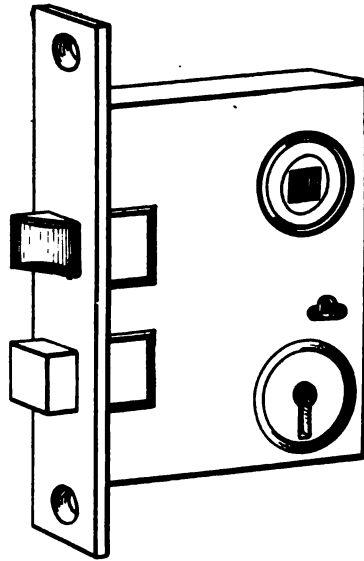


Fig. 35. Latch with Key-Bolt.

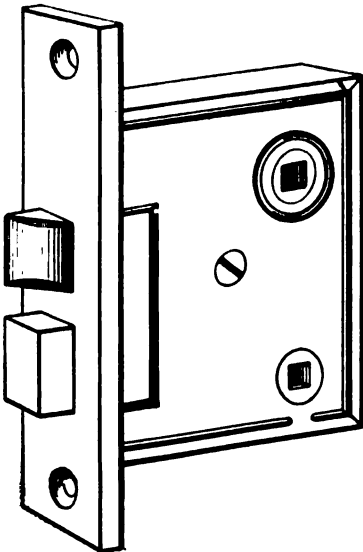


Fig. 36. Latch with Thumb-Bolt.

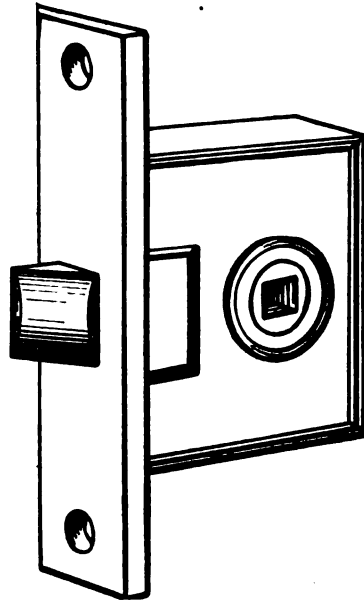


Fig. 37. Simple Latch.

Upon receiving the locks and latches, there should be attached to each a tag bearing the number of the door for which it is intended. If the fixtures are not numbered and it is left for the fitter to sort them out as he proceeds, there will be confusion before half the items are in place.

Aside from the door locks above referred to, there are almost numberless uses to which locks are placed in minor situations; but it is safe to say that not over 10 per cent of locks in such minor situations

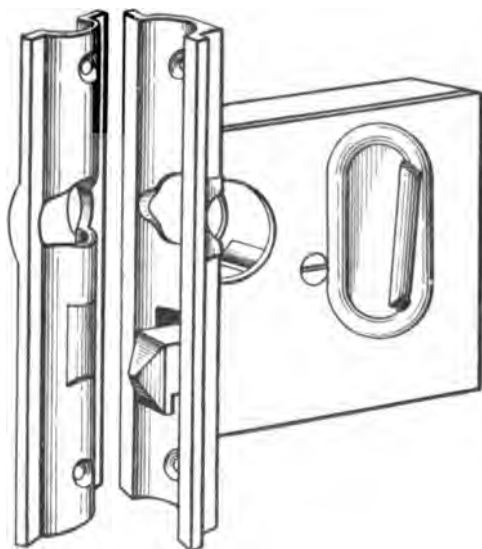


Fig. 38. Sliding-Door Latch.

are ever used—as, for example, on the cupboard door, bureau drawers, etc., which, though always having locks, are rarely locked. It is always better to omit a lock where there is no actual necessity therefor, and when the necessity occurs, to get a lock of the best type. A lock operated by a flat key is usually safe for such places; those with the old bit key are rarely of any protective value.

KNOBS AND ESCUTCHEONS

These are parts in which the vanity of the owner can be—and often is—displayed. The *escutcheon* is the plate through which the key-hole is cut. It is usually combined with that on which the knob is placed, and is the lineal descendant of the escutcheon of chivalry borne by knights and persons of distinction. Careful study of escutcheons on the doors of houses, will show that much of the character of the owner is still indicated thereby.

With this fact in mind in the selection of hardware, special attention should be given this feature. A plain brass or bronze plate and knob is usually a safe selection; but even then such items as its thickness or the way the edge is finished tell of conditions governing

its selection. When the design calls for something more elaborate, it is a mistake to be confined to simple, plain work; but under no circumstances should a knob and escutcheon of elaborate or ornamental character be selected simply on account of such character when the surroundings do not call for display.

The escutcheon, at the point where it receives the shank of the knob, should always, even in cheap work, be so enlarged that it will project over the shank of the knob at least a quarter of an inch and fit closely; this stays the knob and gives it a firmness when gripped not otherwise obtained. The escutcheon plate should also be long enough to extend both above and below the lock; if it does not do so, the screws that fasten it in place can rarely be long enough to hold it firmly, as the side of the lock is usually within $\frac{3}{8}$ or $\frac{1}{2}$ inch from the surface of the door. The screws securing an escutcheon should always extend one inch into the wood.

A great variety of materials are used for both knobs and escutcheons—wood, glass, iron, brass, bronze, and metal plated with silver or even gold—and designers have produced many very artistic as well as many very much over-elaborated forms, which are easily cast in metal—sometimes with unfortunate ease, as it permits the reproduction of designs cheaply and has therefore encouraged their use in many cases where it would have been better to omit a large part of the ornamentation. This cast ornament is an American feature of hardware, that produced in Germany, France, or England being more generally of the wrought type, artisans in those countries being skilled beyond the American in forged work.

The *knobs*, and the *spindle* that connects them—which together operate the latch—are primarily mechanical contrivances, and should be considered as such. The old scheme of making a solid spindle which was secured to both knobs by screws through the shank of the knob running into the nearest hole in the spindle, the play being taken up with thin washers, was always bad, inasmuch as, when enough washers were put in to make the knob feel solid and to prevent its rattling, it was usually so tight as to bind. The screw always works loose, and being small is lost as soon as it drops out. Before a new screw is found, some of the washers very likely disappear; and if new ones are not obtained, the knob remains permanently loose.

Many devices have been provided to do away with these defects

in mechanism. In one of these devices, the spindle end is in three pieces, the middle one wedge-shaped. A screw through the shank bears on this wedge-shaped piece, thus expanding the two others

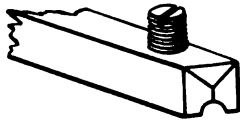


Fig. 38. End of Expanding Spindle.

against the sides of the slot in the shank (see Fig. 39). In practice it is found that this screw when set hard against the wedge does not work loose; before it is set, the knob can be most delicately adjusted without washers; and if the screw should work loose, notice would at once be given by the slipping of the knob before the screw was lost.

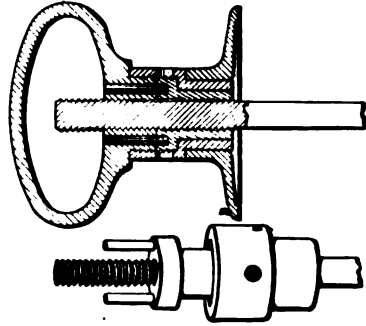


Fig. 40 Knob-Holding Device, Adjusted by a Thread.

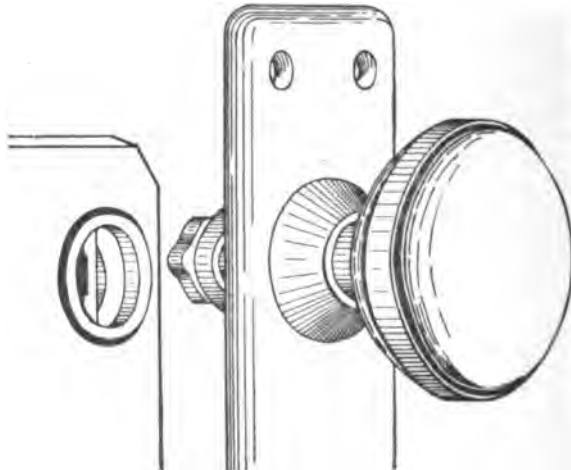


Fig. 41. Knob-Holding Device without Spindle.

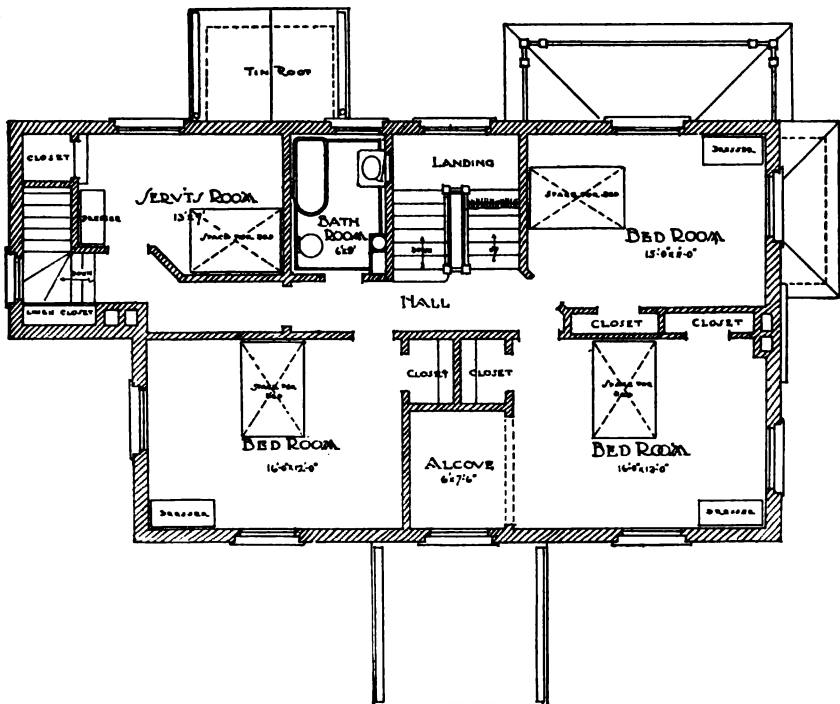
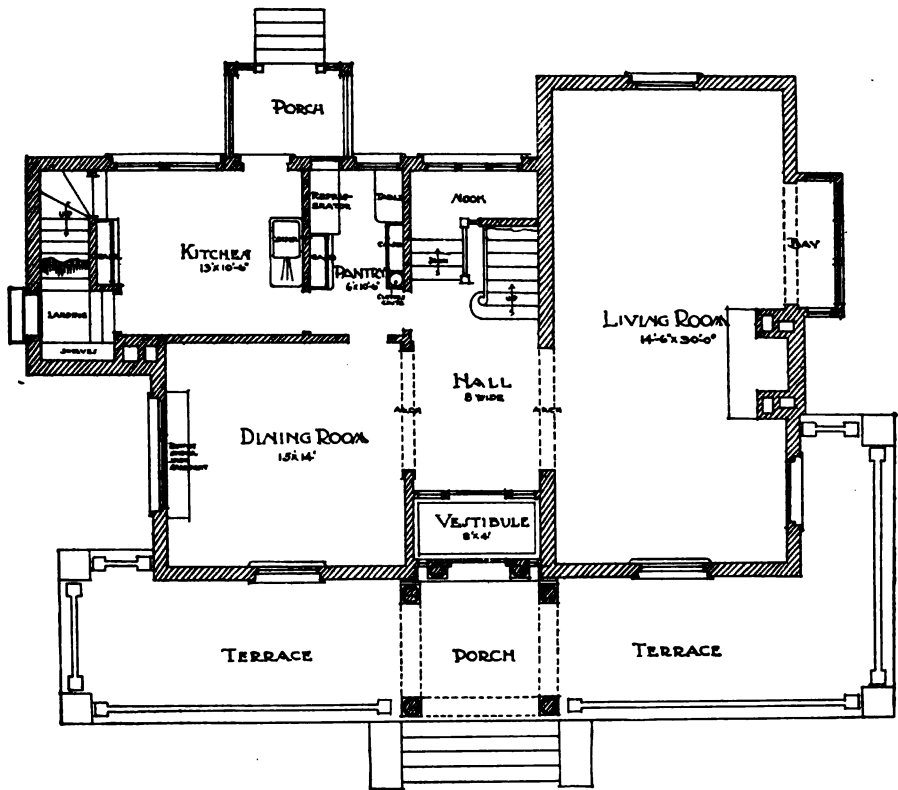
Another but somewhat more expensive device is that illustrated in Fig. 40, in which the knob can be delicately adjusted by a thread so that an exact fit can be obtained.



HOUSE FOR MR. R. H. CAMPBELL, PEORIA, ILL.

Herbert E. Hewitt and Frederic J. Klein, Architects, Peoria, Ill.

Exterior, Brick Veneer of Clinker Brick; Slate Roof. Built in 1906. Cost, \$6,000. Including Plumbing and Furnace Heating. First Story, Oak Trim and Oak Floors; Second Story, White Enamel With Birch Doors. Plans of First and Second Floors Shown on Opposite Page



FIRST AND SECOND STORY PLANS OF HOUSE FOR MR. R. H. CAMPBELL, PEORIA, ILL.
 Herbert E. Hewitt, & Frederic J. Klein, Architects, Peoria, Ill.
 Front View of House Shown on Opposite Page.



There are other devices in which the spindle is entirely dispensed with, and the knobs are slipped into the lock-case independently of each other, as in Fig. 41.

Where locks with pass keys are used so that stopwork changes the latch into a lock, it is desirable that one side only should be affected. The spindles of such locks are, therefore, jointed in the lock with a swivel-connection which allows at all times a free movement of the inside knob or key (see Fig. 42).



Fig. 42. Spindle with Swivel-Connected Ends.

Door knobs should be from $6\frac{1}{2}$ to 7 inches in circumference, whether round or oval, to be gripped with ease; if larger, they should accompany locks which allow them to stand far enough out from the finish to prevent the hand from being pinched or bruised in turning the knob or opening the door. This distance, for ordinary knobs, is given under *Locks* as $2\frac{1}{4}$ to 3 inches, which distance should be increased if a larger knob than ordinary is used. A perfectly plain knob is rarely out of place, while any attempt at ornament is more than likely to appear so. For ordinary work, *spun brass* knobs wrought from thin sheet metal (Fig. 43) are very serviceable, and have the appearance of the genuine cast metal. With the plated butts, they make a good combination (though they will not stand blows without indentation), and for most purposes are as serviceable as the cast metal. In better work, however, the cast brass or bronze should preferably be used, in which the metal is cast from $\frac{1}{8}$ to $\frac{3}{16}$ inch thick; these are the strongest type used.

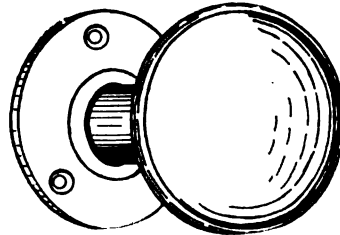


Fig. 43. Spun Brass Knob.

For the last few years there has been a tendency to adopt the types of Colonial days, and nowhere is this tendency seen more than in hardware. And with these designs have come some of the olden appliances, the most prominent of which are latches and knockers. The former are most useful, and, when applied in proper locations,

have a charm which knobs do not possess; but in the case of mortised fixtures of the type usually operated by knobs, they are frequently—in fact, generally—out of place.

Knockers as now used are only for ornament, being rarely used by callers for summoning the inmates of the house.

SASH HARDWARE

In all the range of house hardware, there is none so unsatisfactory as that used in connection with window-sashes. This is not altogether the fault of the hardware, as the customs regulating the manufacture of the sashes themselves make them the most flimsy part of house construction. The glass is wide, and the meeting rails narrow. Sooner or later someone tries to force up the lower sash when “stuck,” by pushing violently on its top rail, or tries to pull down the top sash by pulling on its bottom rail; these operations pull the rails away from the glass, and if, when “fitted,” there was not considerable play, the sashes never come together again. Any sash-lock adapted to such a position must necessarily be far from exact in its working. All work perfectly in the model; few work at all on the real sash. Therefore, in selecting this fixture, it is wise to pick out the strongest which will allow for variation in the rails, and, before purchasing, to visit some house in which they have them installed, in order to see how they work. The material of which sash-locks are made makes little difference, as they are generally out of sight. Little attention need be paid to representations that certain kinds can be opened by means of a thin blade inserted between the sashes from the outside; for, after one has seen the difficulty of working them from the inside by the usual means, he will never be troubled by the thought of anyone working them from the outside with a putty-knife.

There are certain kinds which throw up the arm against the glass of the upper sash when unlocked. This kind should not be used, as they at once give notice to anyone outside, if the window has been left unlocked.

Window pulls or handles on the lower sash are always very difficult things to get a “purchase” on with the ends of one’s fingers when the sash “sticks;” and while the socket in the top sash with a pole and hook to move it, is a trifle the most exasperating of any part

of window hardware, manufacturers have as yet failed to remedy the trouble.

There are on the market quite a large number of complicated devices for operating sashes, either swinging them into the room or sliding them up and down; but in practice the old trouble of flimsy sash construction makes such devices of no more value than those of the old form. It is doubtful whether any remedy will be found until custom requires the use of smaller glass, of sash bars to stiffen the sash, and of better carpentry work in fitting, and requires owners to keep all parts of sashes and frames thoroughly oiled to prevent the constant absorption of dampness, thus preventing swelling and shrinking with their concomitant effects of sticking and rattling.

When sashes are hung at the side—as is frequently the case—they should swing outward; if they swing inward it is difficult to keep out storm water. For holding them at any required angle, bars are

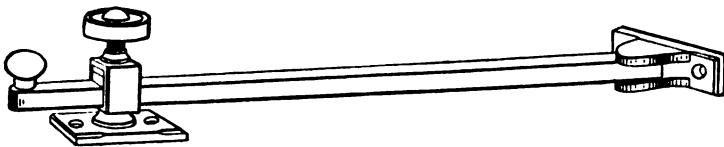


Fig. 44. Sash Fastener.

made with clamp screws (Fig. 44). These work very satisfactorily; but, unless great care is exercised to leave the sash always firmly clamped, sudden wind may wreck the sash and glass, leaving no protection from the storm. As a general thing, accordingly, it is better to retain the old sliding type of window, especially since, with swinging windows, the use of outside blinds is impossible.

The *sash-pulley* (Fig. 45) is out of sight, and often almost anything in the way of material and make is considered good enough. This particular piece of hardware, however, receives so much wear, and is capable of wearing out so much good window-cord, that, if the future is to be reckoned with, care should be taken in its selection. First of all, the wheel should be as large as possible, as the constant crimping of the sash-cord over a wheel of short radius rapidly destroys the fibre, so that after giving great annoyance for a time by becoming caught in the wheel, the cord finally breaks and lets the weight drop to the bottom of the pocket.

For plate-glass windows or wide, heavy sash, chains are generally employed. They are composed of links which follow the curve of the wheel (Fig. 46), and are not easily worn out. The groove in

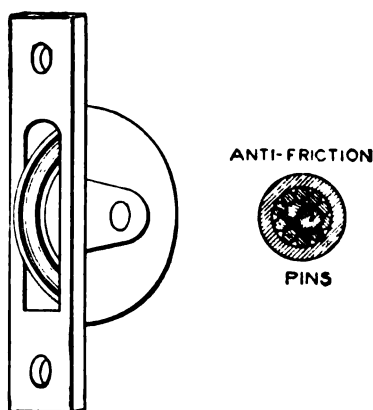


Fig. 45. Sash Pulley.

the wheel should be square to conform to the lines of the chain, and not as for cord (see Fig. 47).

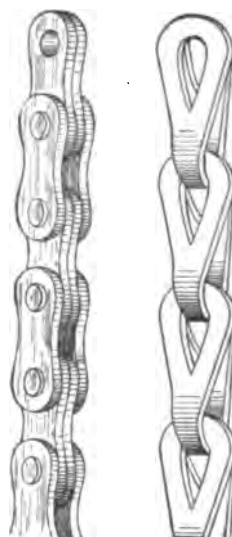


Fig. 46. Sash Chains.

The pocket in which the window weight runs, should never be less than two inches in depth (crosswise), nor the pulley-style less than $\frac{7}{8}$ of an inch thick. Thus it will be evident that to allow the weight to hang in the middle of the box, the wheel of the pulley must be not

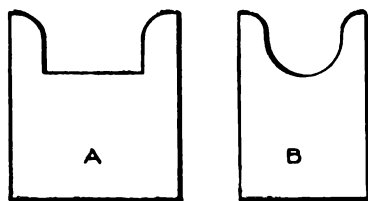


Fig. 47. Sections of Sash Pulley Rims—
A, for Chain; B, for Cord.

less than two inches in diameter *on its running face*; that is, the diameter of the wheel should always be equal to the thickness of the pulley-style *plus* one-half the depth of the box (see Fig. 48). The diameter here indicated is considerably larger than that of the

pulley wheel used in common practice. If, however, a smaller wheel is used, not only is the cord rapidly destroyed by the constant crimping, but the weight "drags" on the back of the pulley-style, making the operation of the sash difficult and noisy.

Pulley wheels are generally measured by manufacturers and dealers, to the outside of the flanges, so that a wheel two inches on

the running face is often styled a 2½-inch wheel. The money invested in such a wheel is gained many times over in saving the annoyance and expense of broken sash-cord.

If the pulley is steel-bushed and has roller bearings, it will be better in the long run, and these items add little to the expense. The running face of the wheel should be smooth; and all parts may be of iron, without detriment to the appearance or the usefulness of the fixture. A plain brass or bronze face and wheel are to be preferred, however, if the small additional expense is not a bar.

The pulleys usually put in stock frames are 1½-inch iron pulleys costing about 50 cents a dozen; and 10 cents a dozen is usually added for each additional quarter-inch in the diameter of the wheel, though the mill man will often want a little extra for making the frame "special" in case the larger wheel is used. The brass wheel with roller bearings and brass face will cost about three times the above price—or, possibly, 50 cents extra for each window.

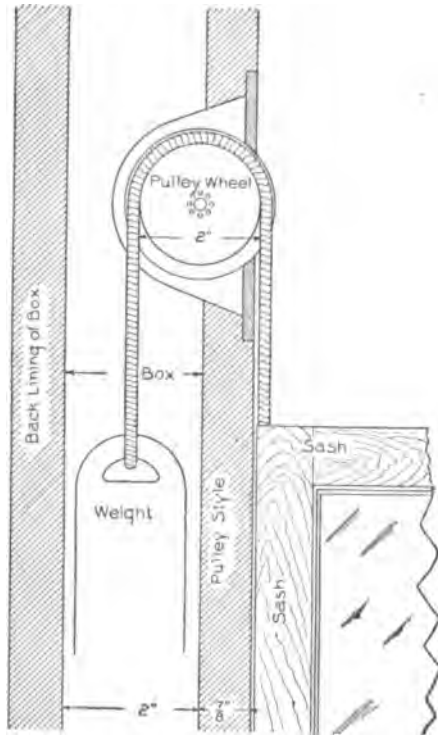


Fig. 48. Section of Pulley and Pulley-Style; Showing also Sash and Weight.

There are on the market very useful pulleys over which the sash-cord can be carried to boxes several feet away (Fig. 49). Pulleys of this type can be used where the mullions between windows are too small to carry the weights. These pulleys dispense with the necessity for lead weights, which are expensive and are usually crowded into boxes so small that they work unsatisfactorily. By the use of combinations of these pulleys, the cord can be carried an indefinite distance to a box capable of receiving a large iron weight, and

the width of the mullion can be reduced to the minimum thickness.

Sash-cord is a very important item, and braided cotton cord is probably the cheapest in the long run. It is better to get a *small* rather than a large size. The wearing of the cord is due to the fact that in passing over the pulley the inside or the part against the wheel is compressed or crimped, while the opposite side is stretched, thus producing a constant wear and strain of the fibre of the cord, which finally breaks it down. It will be evident that this disintegrating action will increase with the larger diameter of the cord. A cord just large enough to hold the weight safely, is the best. A simple test is to suspend four of the heaviest weights to be used, by one cord; if it will hold them, it is sufficient size to carry the one weight.

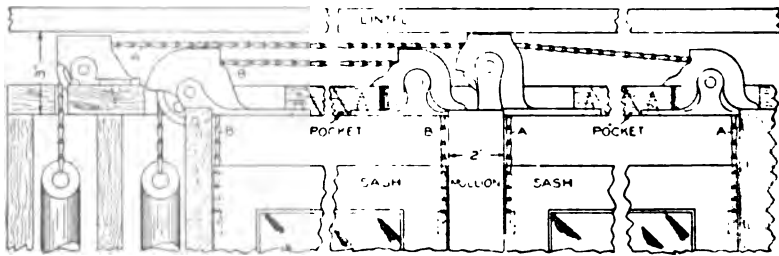


Fig. 49. Pulley Arrangement for Carrying Sash Cord to Distant Boxes.

Taken as a whole, the window—with its lock which rarely works, its exasperating pulls, and its sash-cord broken when most needed—is one of the oldest, and still one of the greatest, of modern inconveniences. Undoubtedly the first step necessary to make the window more satisfactory, is to make the sash narrower and cut the glass smaller, with substantial muntins, so that the sash will be firm. This, with a little better workmanship on the frames, will, with present appliances, make a very satisfactory window.

MISCELLANEOUS HARDWARE

Bolts. The bolt is one of the oldest and simplest contrivances for securing different parts in a desired position, and is still a most necessary item of hardware. Here, weight of metal counts for as much as, if not for more than, in most other items of hardware. This weight should be balanced in the different parts to insure strength

of the whole. A heavy moving rod, for example, in some bolts, is made to engage with a thin keeper-strap attached to the base by very slight tenons headed over, so that, while it is probable that it would take 2,000 pounds pressure to break the rod, a pressure of 100 pounds might be sufficient to force the keeper-strap from its base (see Fig. 50). Inasmuch as a bolt cannot be *picked* like a lock, its value lies in its strength to resist force, and this should always be remembered in its selection.

As a general rule, all bolts operated by a sunken thumb-piece (Fig. 51) should be avoided, for, if they "stick"—and they generally do—very little power can be exerted by the end of a thumb. There are many lever and knob devices which permit the direct application of a considerable power. Two forms of these devices are shown in Figs. 52 and 53. This point should receive attention in selecting bolts for the standing leaf of a double door, or for cupboard doors.

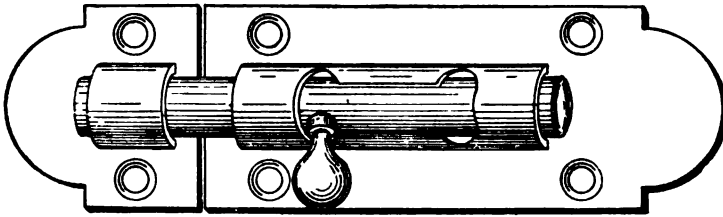


Fig. 50. Common Type of Bolt with Keeper-Strap.

The rod on a bolt should be tapered at the end, as the two parts rarely come exactly together so as to permit the rod to enter the keepers; if it tapers, it will, as it enters, draw the door to its proper position.

For *drop-front drawers* in linen closets, it is necessary, in order to save space, to use *flush hardware*—that is, hardware which does not project beyond the drawer front, which should be just inside the closet door. Fig. 54 illustrates a *flush-ring cupboard catch*, which will serve the purpose; it is of the type usually seen on store showcase doors; in fact, such doors throughout are good examples of the arrangement of drop-front drawers. A large size of fixture should always be chosen. Stay-chains should be put on each end of these fronts, to prevent them dropping below a horizontal position, in order both to prevent straining the hinge and to provide a strong extension to the drawer when open, whereon to lay linen.

In place of a bolt, to secure the standing leaf of a cupboard door, a *knee-catch* (or elbow) is often used (Fig. 55). This is more conveniently operated than a bolt, requiring no action other than shutting the door to catch, and a simple motion to open. The largest size of this fixture should always be used.

Chain bolts (Fig. 56), are most useful in allowing the door to be opened a few inches, and yet locking it with a partial security. They

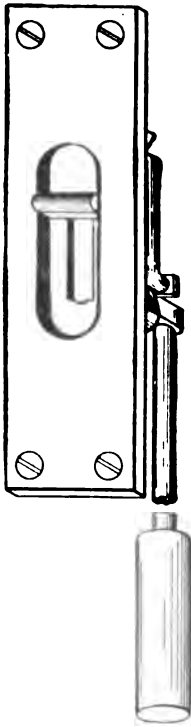


Fig. 51. Bolt with Sunken Thumb-Piece.

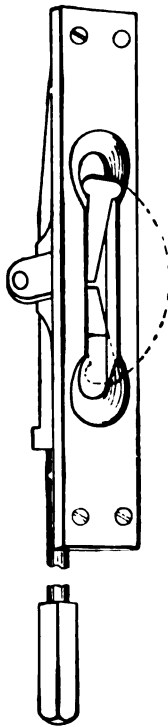


Fig. 52. Lever Bolt.

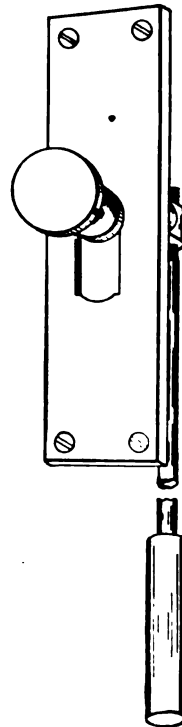


Fig. 53. Knob Bolt.

are often used to permit ventilation, or to allow the inmate to learn the character of a caller before fully opening the door.

The ice-box door of the north piazza (see Fig. 69) needs special attention, as a slight crack will allow the warm air to reach and meet the ice. A clamp which will force the door into its frame, must be used. Fig. 57 shows a good, strong form of such a clamp; ordinary strong hinges are suitable for the door.

Door Checks and Springs. These items are referred to under the heading *Butts*. A door check and spring consists of a very strong spring applied to close the door suddenly, and, in connection with it,

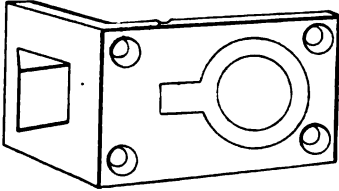


Fig. 54. Flush-Ring Cupboard Catch.

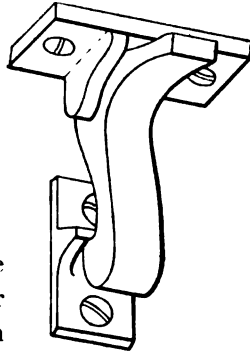


Fig. 55. Knee-Catch.

a cylinder in which a piston runs freely until the door is nearly closed, when either the air or some oil or other liquid which cannot be frozen in the cylinder checks the rapid piston action, so that the door is closed easily and without a slam (see Fig. 58). These checks cost in place from \$4.00 for light doors, to \$7.00 for those of heavy type. They are fastened on the top of the door, and are no disfigurement.

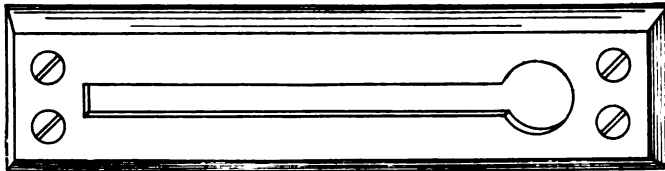


Fig. 56. Chain Bolt, Allowing Door to be Partially Opened

These springs are always in action, so that, if it is ever desired to leave the door open, some appliance must be used to accomplish

this purpose. As they do not generally permit the doors to swing back against the wall where hooks could be used, *foot-bolts* are placed on the bottom rail; these have a flat top which can be pressed by the foot into a slot in the floor.

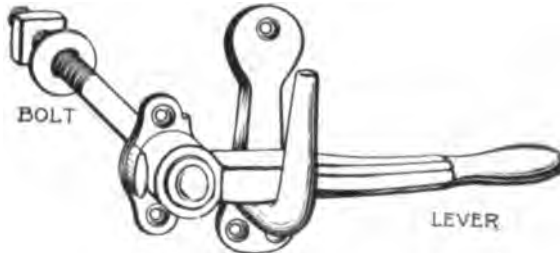


Fig. 57. Refrigerator Clamp.

There are also on the market types of patented bolts, one of which, when pushed by the foot, is forced by a strong spring against the floor; the end of the rod is protected by a heavy rubber buffer, the

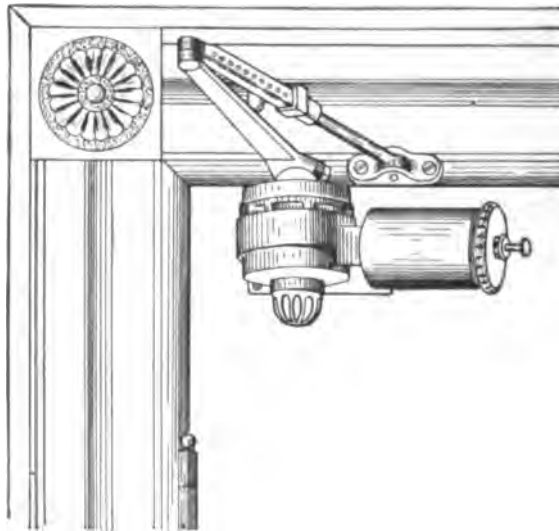


Fig. 58. Door Check and Spring.

friction of which on the floor is sufficient to hold the door in any position (Fig. 59). Fig. 60 is another convenient type of door-holder, its method of operation being self-evident.

Kick plates and *push plates*, while not often needed in house hardware—except, possibly, for double-acting doors—are plates of metal not less than $\frac{1}{16}$ inch thick screwed onto the face of the door to protect it from wear. The kick plate, as its name implies, is the plate put on the bottom rail where persons are likely to apply the foot in kicking the door open. In public buildings, such plates are often put on for ornament; and also, where the surrounding finish is of marble,

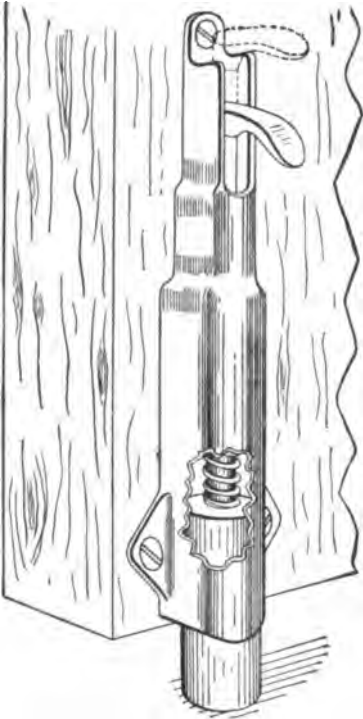


Fig. 59. Door-Holder Actuated by Spring Operated by Foot.

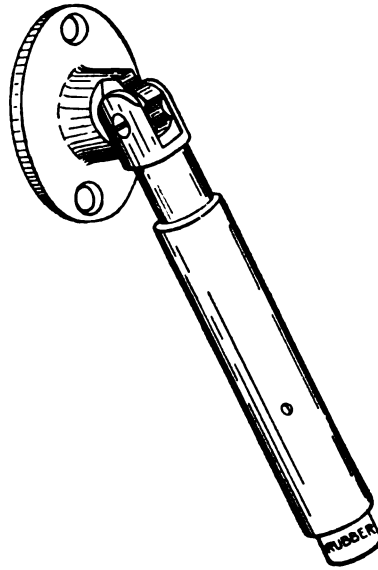


Fig. 60. Another Type of Door-Holder.

these plates protect the finish of the doors from the soap and often acid, used in cleaning the floor and base marble. It is needless to say that for such uses, the perfectly plain plate is alone appropriate.

Push plates are used to protect the finish of doors where persons push them open with the hand. If they are not used, the finish on the doors soon shows where the pressure is applied, and later it will be completely worn off.

Neither kick plates nor push plates should be used except where there is a necessity therefor; they are not properly subjects for ornamental treatment; and they add materially to the weight of the door, which in its lightest form is a severe strain on the butts. The plain face of the metal shows any indentations, and it is difficult to keep bright. Careless cleaners, moreover, are apt to rub off the finish of the wood, so that the plates become surrounded by an unsightly fringe of unfinished wood.

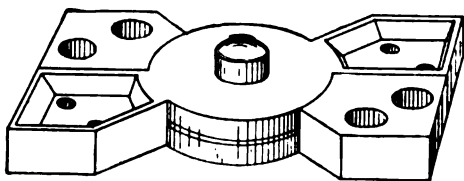


Fig. 61. Transom Fixture for Vertical Pivoting.

back into pockets in the partitions. There are on the market many devices for trucks, generally good and inexpensive; but their installation and the framing incident thereto are matters of delicate workmanship, and if future trouble is to be avoided, it is well to see that appliances of this character are put in only by *mechanics* of known skill. After the doors are in and the partitions plastered, is a bad time to do the work over.

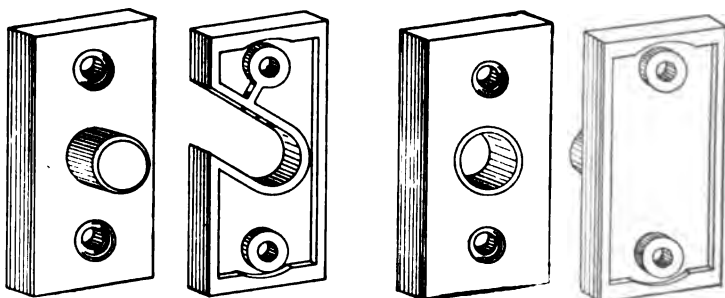


Fig. 62. Transom Fixtures for Horizontal Pivoting.

Transom Hardware. Transoms are generally hung from the top or bottom with fast-pin butts; or with pivots in the center of the top and bottom rail allowing them to swing at right angles with the transom bar, which is called *pivoting vertically* (Fig. 61), or with pivots in the center of each side to allow the sash to swing to a horizontal position, which is called *pivoting horizontally* (Fig. 62).

It is not necessary to refer to the butts here, except to say that

it will generally be more satisfactory to pivot the transoms than to hinge them, for, when hinged, it is necessary for the transom lifter to carry the full weight of the sash, which it very often fails to do satisfactorily; whereas, when pivoted, one side balances the other so that the lifter has nothing to do but overcome the friction of movement. These pivots are simple and easily applied.

There are on the market patented *friction pivots* of various types, which, while allowing the ordinary pivot action, hold the sash in any required position, thus doing away with the lifter. The transom, either pushed or pulled by an ordinary window pole-hook to the position desired, remains as left. To lock it in place, a large-size, heavy spring-ring catch is put in the top rail, which can be opened with the hook on the pole.

The transom lifter (Fig. 63) is an item in which little improvement has been made in the last generation. Its operation is generally unsatisfactory, and its use should be avoided if possible; but when it is necessary to use a lifter, it is advisable to get the heaviest rods, to prevent the unavoidable spring.

Cellar-Window Hardware. In this connection the hinging and locking of small cellar windows, above grade, may be considered. The sash are usually light; and it is not best to swing any portion out, as they are so near the ground that the portion turned out would be liable to damage. Also, it is often necessary to pass things through the window into the cellar, and this requires the full opening. The sash are particularly liable to shrinkage and swelling—more often the latter—which cause them to stick in the frame. Moreover, the cellar window is a favorite point for the burglar's entrance. It is



Fig. 63. Transom Lifter.

therefore usually necessary to hinge cellar windows with fast-pin butts *at the top*, to swing inward and up against the joists, and to have a strong handle for pulling them out of the frame when they stick, and a simple lock. Fig. 64 shows a simple but efficient device for fastening a cellar window. The screws in the part on the frame

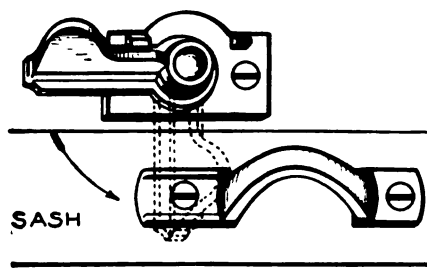


Fig. 64. Cellar-Window Fastener.

should be the longest obtainable; and the rivet or bolt holding the swinging part to the plate should be strongly secured, so that both points will resist any ordinary pressure from the outside. If a burglar brings his "jimmy," it is not likely that any appliance that can be used on the inside

will resist its pry. For holding the window open, a strong wire hook and eye will be sufficient.

Wardrobe Hooks. In the selection and arrangement of wardrobe hooks, careful study will greatly increase the capacity of the usual *hanging space*. It is a mistake to select one type of hooks, and use that throughout; and also to consider that hanging space is confined to the walls. For ordinary items, common strong wire hooks (Fig. 65) can be used, set closely together; and if there is depth to the closet *flies* can be hinged so as almost to double the hanging capacity. In Fig. 66, *A A* represent the flies hinged on the wall. Arrangements of this kind, however, are not suitable for the hanging of garments which are required to retain certain shapes. For these articles, long horizontal hooks or pins (Fig. 67) should be provided; on these, certain garments can be hung close to the wall; while such items as coats can be placed on two, one in each arm, so that they will retain their shape and hang clear of the pieces against the wall.

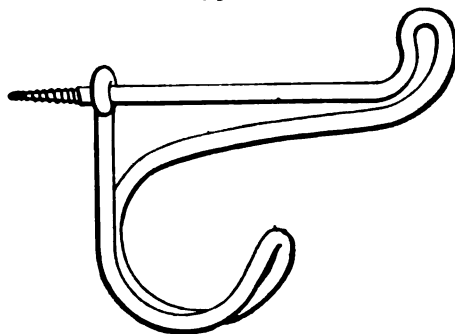


Fig. 65. Common Type of Wardrobe Hook Made from Wire.

In the more expensive materials, many special types of hooks are made for special purposes. They generally have a lower, minor hook, while the upper arm extends outward and upward for hanging hats; in other cases the upper arm extends out nearly horizontally, and

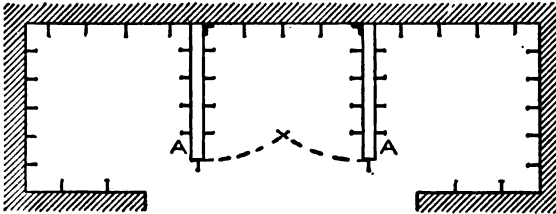


Fig. 66. Swinging Files Hung in Closet to Economize Hanging Space.

then dips to support a garment clear of that below. A very useful article of furniture is a *tree* or *standard* (for use in bedrooms), to which are secured a large

variety of hooks adapted to the various items of the wardrobe for daily use.

FINISHES OF HARDWARE

It is necessary that hardware should have some special finish; and, as in the case of wood or marble or any other fine material, the object of the better finishes is to bring out and intensify the qualities of the material itself. Cheap hardware is generally japanned so as to present a smooth, shiny black surface; this is an excellent coat for wear and for protection against rust, and is not of objectionable appearance. Where ordinary unfinished hard-

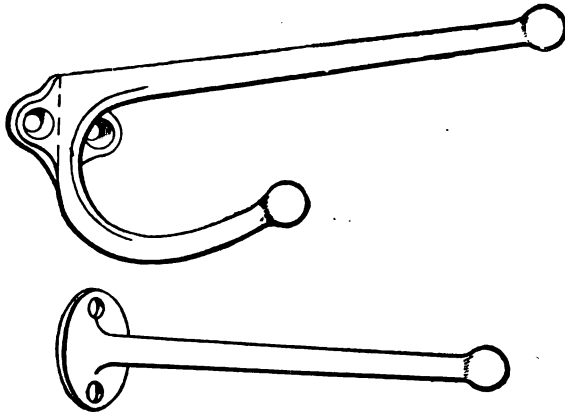


Fig. 67. Long Wardrobe Pins and Hooks.

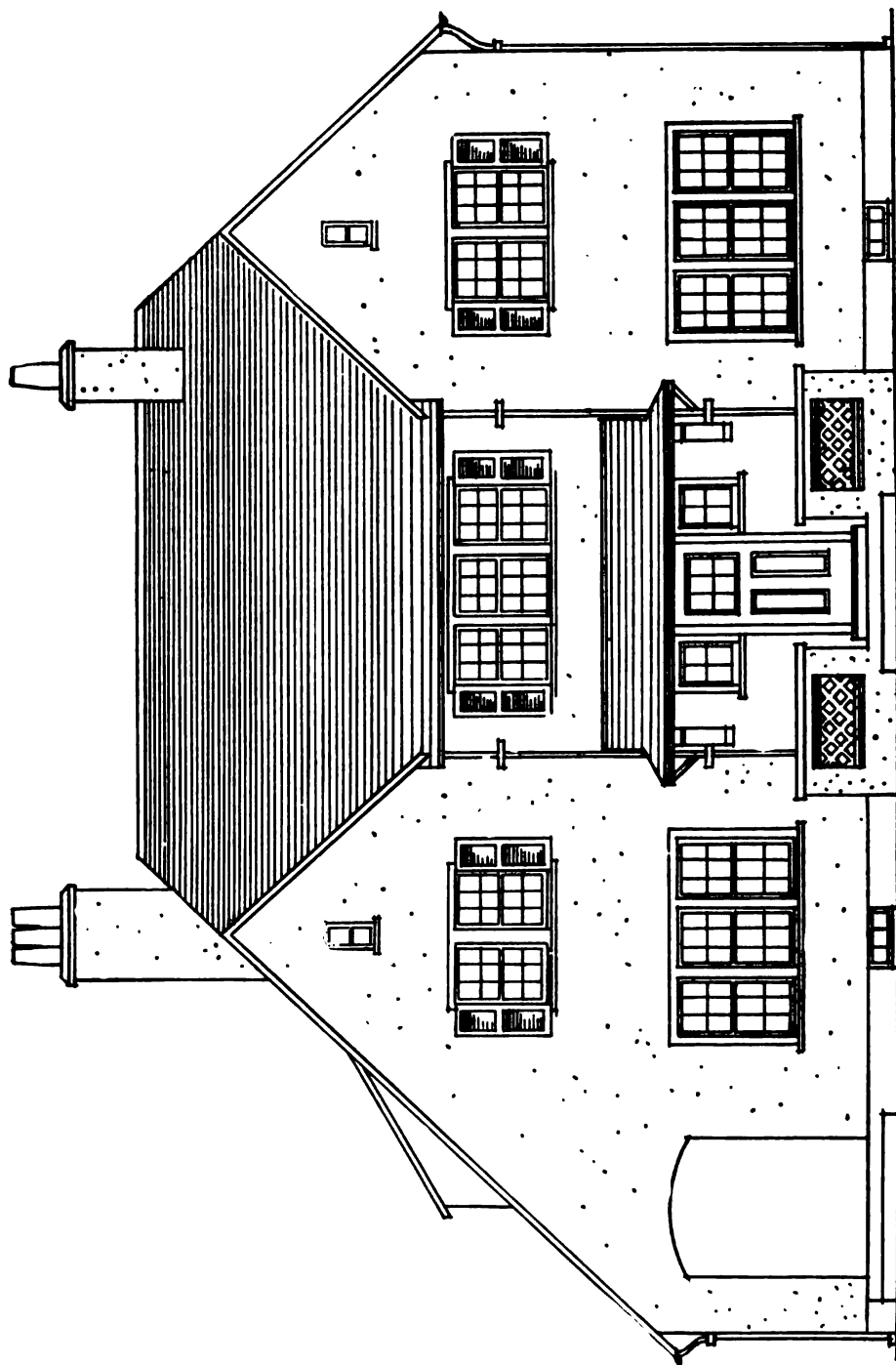
ware is used, it should be painted, varnished, or oiled at the same time the wood to which it is secured is finished. It is also well to paint the surface which presses against the wood; if this precaution is not taken, moisture may get behind, and resulting rust discolor the wood below.

Wrought Finish. Wrought iron, forged, is not often used except for specially designed work. When it is used, it should be finished under the hammer; that is, all the marks of the blows should be left, and no attempt made to file or smooth up the parts. The surface can be coated later with lacquer or some thin iron paint which will not obliterate the texture, in order to prevent rust; but under no circumstances should a coating in the nature of heavy lead and oil paint be used.

Cast Bronze and Cast Brass. These materials (the former being from 85 to 92 per cent copper, the balance tin and zinc; the latter from 60 to 70 per cent copper, the balance zinc and lead) are the most common finishes used in good hardware. They are sold at comparatively low prices, the finish being generally in the polished natural color, protected by a colorless lacquer. There are, however, many variations from this practice—such as strong greens—the results being produced by the action of chemicals artificially applied after all mechanical work is done. Some of these effects are very striking, but not suitable unless the surroundings are such as to call for such peculiar treatment.

Bower-Barff Process. This is perhaps the most successful of finishes for interior hardware. It is applied to either cast or wrought iron, and produces an intensely dense and deep black color free from gloss, over which no protective coating is needed. It, however, is expensive—equal in cost to solid cast bronze; and moreover, it is not so tough as brass or bronze, the process tending to make the metal brittle. This finish is not suitable for outdoor work in damp climates, where rust is apt sooner or later to attack it in such a way as to disintegrate the surface. While constant protection with lacquers might prevent or check this action, it is better practice, in exterior work, to use a finish adapted thereto.

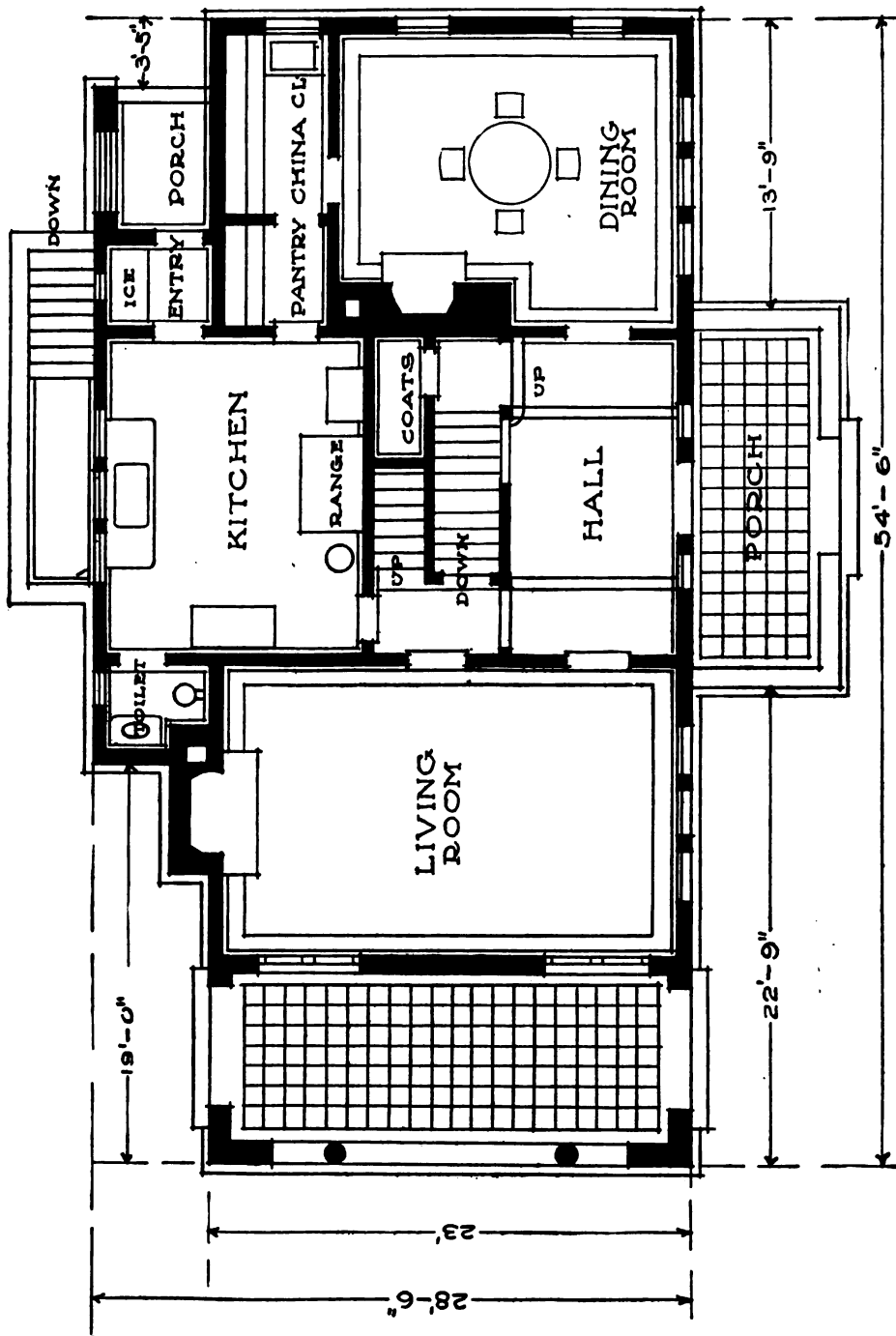
Plating. As previously stated, this form of finish is used extensively in connection with butts, to make them correspond with the genuine brass or bronze used in knobs, etc., where plating would soon be worn off. For such purpose it is appropriate and enduring; but for exterior work, plating should not be used. Silver and gold plating are employed to a limited extent, but on account of the expense they are little used except in specially designed work.



FIRST PRIZE DESIGN, GARDEN CITY COMPETITION, LONG ISLAND, N. Y.

J. Lovell Little, Jr., Architect, Boston, Mass.

First-Floor Plan Shown on Opposite Page. For Second-Floor Plan, See Page 31A.



FIRST-FLOOR PLAN. GARDEN CITY COMPETITION LONG ISLAND, N. Y.

J. Lovell Little, Jr., Architect, Baiton, Mass.

Front Elevation Shown on Opposite Page. For Second Floor Plan, See Page 815



SELECTING AND BUYING HARDWARE

There is no part of the building process in which the necessity for absolute *system* is greater than in selecting and making out a bill of Hardware. To illustrate this point, let us take the example of the Colonial House of which detailed plans are given in the section on "Estimating" in Volume II. It is surprising to find that there are required approximately 50 types, exclusive of nails, screws, bolts, etc.; and that there are 1,100 pieces of these various types required in this one building. Hardware is expensive *to buy*, and expensive *to put on*. If these eleven hundred pieces get mixed, a large amount of valuable time is consumed in getting them arranged; if too much is bought, the excess is a loss, as it is difficult to return broken lots; if not enough is purchased, the loss of time in going over the work again and again to find what is missing, is expensive; and waiting to have delivered the last belated portions of material still lacking, is exasperating.

Therefore the first thought should be to place the whole matter in such orderly shape that every point in connection with the selection, arrangement, and distribution is settled, and so clearly noted that future uncertainty relative to any point will be impossible. It is also necessary to determine the exact cost of the entire bill before deciding on any of the types; and only with a complete list is it possible to find just the relationship between the cheaper and better lines.

For all these reasons, a most useful purpose will be served if we now proceed to set forth in detail, step by step, a scheme for preparing bills of hardware, so arranging the items that definite and intelligent decision can be made, and serving also as a guide to the expeditious and accurate arrangement and distribution of the materials to the proper points for installation.

It is evident that the types at each point must be practically the same for all grades. Thus, for instance, a door requires butts (4 x 4 or 5 x 5 inches) irrespective of whether they are wrought-iron, japanned, bronze-plated, or solid cast bronze. Two knobs are required whether "Mineral" jet, wood, glass, or bronze is used. Therefore, in proceeding, the question of *quality* of material will generally be disregarded, except in cases such as knobs, where it is desirable to use a better material for the selected type in the major rooms and a cheaper material in the minor.

After the list is completed, it can be made out in three forms—the first designating the *cheapest* line appropriate; the second designating a line of *intermediate grade*; the third, the *best grade* which is suitable.

In preparing these three lines, there are many appliances which will not be varied. In the case of locks, for example, a thoroughly good grade should be used in the cheap line; there is no advantage to be gained in selecting expensive locks of the more intricate mechanism and more elaborate design, even for the better-grade schemes.

After these bills have been prepared, figures can be readily obtained on each, so that an intelligent decision based thereon can be made.

Listing the Items. The first step is to lay out the floor-plans, showing every point at which hardware is required (Figs. 68–71). Doors should be indicated with their swing *right-hand* (*R. H.*) or *left-hand* (*L. H.*). In the case of windows, it can generally be taken for granted that small cellar windows, unless otherwise indicated, are hinged at the top to swing up against the first-floor joists, and that all other windows, unless otherwise indicated, are *double-hung* with cord and weights. The location of china closets, pantries, linen rooms, etc., in which are cupboards, drawers, hooks, etc., should be clearly shown. These plans should be very simple, carrying no details except those necessary to indicate the need for hardware at the various points. It is better to make the drawings on tracing cloth or onion skin, so that after the hardware is designated thereon, prints can be taken for the use of the workmen.

On these skeleton drawings, every point requiring hardware should be numbered. Thus,

Basement Doors should begin with 1, 2, 3, etc.

“ Windows should begin with 50, 51, 52, etc.

“ Closets, cupboards, etc., should begin with 90, 91, 92, etc.

First-story Doors should begin with 101, 102, 103, etc.

“ “ Windows should begin with 150, 151, 152, etc.

“ “ Closets, cupboards, etc., should begin with 190, 191, 192, etc.

Second-story Doors should begin with 201, 202, 203, etc.

“ “ Windows should begin with 250, 251, 252, etc.

“ “ Closets, cupboards, etc., should begin with 290, 291, 292, etc., etc.

In this way the floor on which any number occurs can be recognized. Breaks in the numbering should be allowed, as it will be

found, in working out the later details, that certain points have been overlooked, and numbers can then be assigned which will not necessitate any rearrangement.

It will be noticed that in the above scheme of numbering, we have subdivided our hardware into three distinct lots—namely, for *doors*, for *windows*, and *miscellaneous items*. It is well throughout

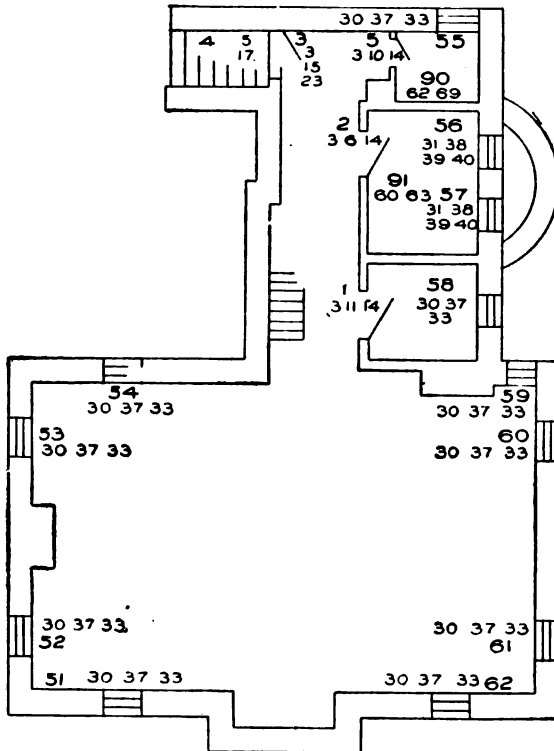


Fig. 66. Basement Plan with Hardware Items Indicated.

to keep these subdivisions entirely distinct, as in this way all liability to confusion will be practically avoided.

The second step is to make a list of appliances which will be required under the various divisions. Thus, under the heading *Doors*, we shall have

Butts of various sizes,
Locks " " kinds.
Etc. Etc.

Under the heading *Windows*, we shall have such items as

Pulleys,
Sash-locks,
Etc. Etc.

Under *Miscellaneous*, the list would include such items as

Hooks,
Drawer-pulls,
Etc. Etc.

Each item in this list should be numbered; and, to prevent confusion, designating letters should be attached, indicating the division

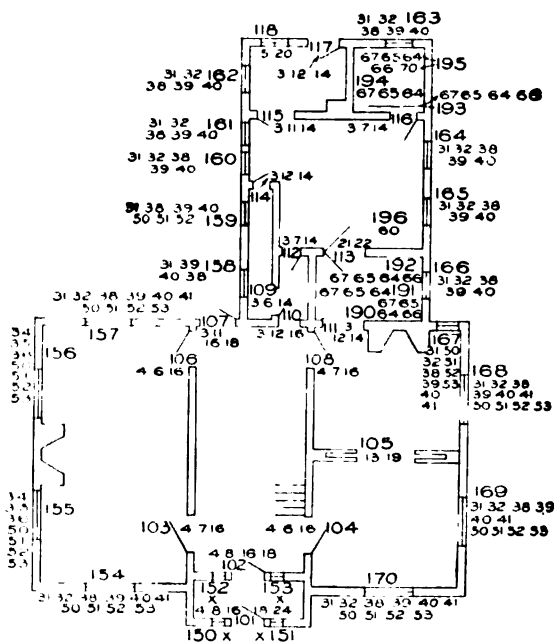


Fig. 69. First-Floor Plan, with Hardware Items Indicated.

to which it belongs. All numbers for door hardware, for example, should carry the letter *D*, as *D* 1, *D* 2, *D* 3, etc.; those for windows should carry the letter *W*, as *W* 50, *W* 51, *W* 52, etc.; and those for miscellaneous items should carry the letter *M*, as *M* 90, *M* 91, *M* 92, etc.

The third step consists in placing on the drawings, under each door, window, or miscellaneous item, the designating numbers of the hardware appliances required, so that it will be possible, by

merely referring to the plan, to ascertain just the hardware that will be required at each point. Several prints of these drawings should be made, as the successful placing of the hardware is dependent on following without deviation the lines thus laid down. The placing of a few items in wrong locations would produce confusion throughout the whole line.

The fourth step is to take three sheets of ordinary section paper ruled to quarter-inch squares each way, and to place on these sheets respectively, up and down at the left-hand edge, the layout numbers of the doors, windows, and miscellaneous items. (See Quantity

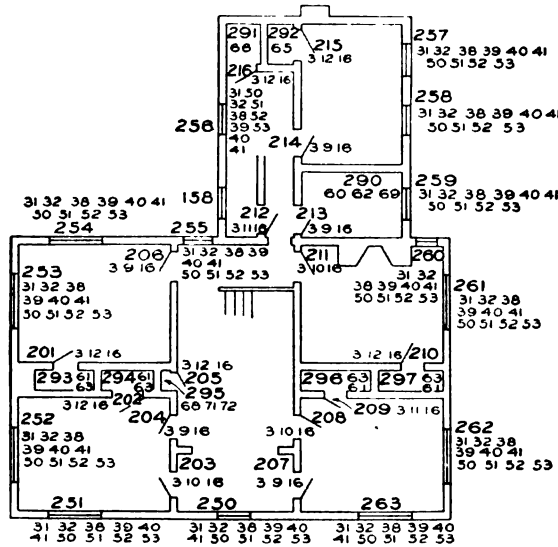


Fig. 70. Second-Floor Plan, with Hardware Items Indicated.

Sheets, pages 52-54.) Also, across the top of the sheets, place the designating numbers of the different items of hardware required under each division. Then, in the squares at the intersections of the lines running from the plan numbers and those dropping from the hardware numbers, note the quantity required.

There will be many occasions when for several doors or windows the same fixtures will be required. This condition is apt to breed carelessness, and mistakes are likely to occur for lack of *distinct consideration of each item*. If, through lack of care, three or four unnecessary appliances are included, their cost will more than offset the entire expense of making a careful bill in the first place.

As an example of how mistakes are liable to occur, note the window indicated between windows Nos. 255 and 256 in Fig. 70. This window, being on the stair, is shown in both the first and second story floors, and the hardware therefor was included in the first-story items. Unless distinct consideration is given to each item, it would be a natural mistake to double the order for this window; it would also be a natural mistake to include blind hardware for 158, 160, 161, and 162; but, by carefully examining the elevations, it is found that no blinds are required. Further, unless the detail sections through the pantry are studied, the arrangements for drawers, cupboard, flour-box are not understood.

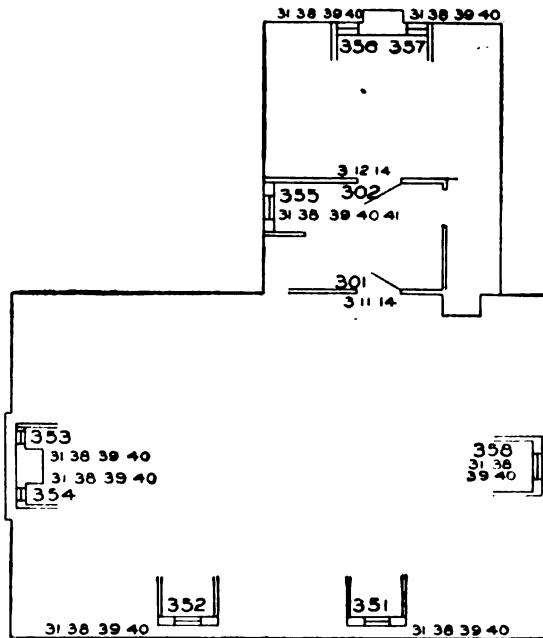


Fig. 71. Attic Plan, with Hardware Items Indicated.

The sheets are completed by adding the numbers in the vertical columns to obtain the exact number or quantity of each item required. The success of this entire scheme depends on absolute accuracy.

At this point it is very desirable that the results be *proven correct*. It is generally useless to go over the work a second or third time, following the original line, since the same mistakes are generally made each time. Some independent line, accordingly, should be selected,

in order to detect errors. A simple method is to add the number of appliances required for all points on the various plans, and then add the numbers on the sheet last prepared; if these sums agree, it is reasonably certain that no mistakes have been made.

For instance, counting the items required for doors throughout, we find we have as follows:

Basement	14	items
First Floor	55	"
Second Floor	48	"
Third	6	"

Total . . . 123 items required for doors.

Adding up our quantity sheet, allowance has to be made when more than one of the items is used at one point. For instance three butts are required for each door, but they are noted on the plan as only one number.

We obtain the total of the items from the quantity sheet, as shown on page 52, as follows:

Under *D* 3, the total $93 \div 3 = 31$ items.

" *D* 4, " " $18 \div 3 = 6$ "

Item *D* 5, is doubled at one point, so that total $3 - 1 = 2$ items

Items *D* 6 to *D* 21, inclusive = 81 items.

D 22 is only one item on the plan = 1 "

D 23 and *D* 24 = 2 "

Total 123 items.

In case the totals do not agree, add each floor on the quantity sheet so as to locate the discrepancy on one floor. When so located, it can be quickly found.

The fifth step is to incorporate the quantities now found in a bill or list which should distinctly state the character and quality of each, and include the requirement that all necessary screws shall be provided. In doing this, the separate items may be described in detail, or referred to under their *catalogue numbers* (if catalogues are at hand). Ordinarily, however, the most economical plan is to take the list to a dealer, and find what he can furnish the cheapest to meet each requirement.

CATALOGUES

It is entirely outside of the province of this paper to attempt to catalogue the hardware now made. There is no line of manufacture

in which the details are more intricate, and few retail or even wholesale stores carry a full line of any particular make. To persons interested in the purchase of hardware, it is suggested that upon request the manufacturers will forward catalogues showing their various lines; or such catalogues can be borrowed from a retail store. Any order for other than the commonplace, low-priced, stock hardware will generally be filled at the factory.

Any prices quoted in any textbook, can be taken only as a general guide; and it must be remembered that prices of hardware are especially liable to fluctuation. In busy times, it is often difficult to obtain a "bill of hardware" even at full market prices; whereas, when a slight easing off in business occurs, manufacturers and their agents not infrequently make material cuts in prices, in order to keep their shops full during the quiet season.

When work on any bill has reached this point, it is evident that the buyer can soon reach a decision as to whether it is necessary for him to buy a lower grade of hardware than he first intended, or whether he can afford a better.

Under the more common, slipshod way of buying hardware a man selects a few of the more prominent items without reckoning the cost of the numerous unlisted class, and is generally disappointed at the conclusion in two ways—first, in finding the number of items, and their expense, about double his first idea; and second, in finding that he has bought a lot of appliances not suited to his wants, costing as much as the items which were desired, but which his lack of forethought and system prevented him from getting.

Following the lines above laid down, our layout plans will appear somewhat as illustrated in Figs. 68 to 71; and our memoranda will have assumed a form something like the following:

Hardware for Doors

- D3 Loose-pin japanned iron butts, with tip, 4 in. x 4 in.
- D4 " " " " " " " 5 in. x 5 in.
- D5 Plain tee-hinges, 14 in.
- D6 Knob-latches, *R. H.*
- D7 " " *L. H.*
- D8 " " stopwork and pass key, *R. H.*
- D9 " " thumb-bolt.....*R. H.*
- D10 " " " "*L. H.*

- D11* Knob-latches, dead bolt *R. H.*
D12 " " " " *L. H.*
D13 Sliding-door latch.
D14 Mineral knobs.
D15 Iron store-door latch, with thumb-piece.
D16 Jet knobs.
D17 Padlock and hasp.
D18 Chain-bolt.
D19 Sliding-door hanger
D20 Refrigerator clamp.
D21 Double-acting butts
D22 Push-plates.
D23 Heavy iron bolt.
D24 Push button for electric bell.

Hardware for Windows

- W30* Fast-pin plain iron butts, 3 in. x 3 in.
W31 Pulleys, 2 in. on running face
W32 Sash-lifts, Hook.
W33 Heavy cellar-window fastener
W34 Loose-pin butts, 5 in. x 5 in., same as *D 4*.
W35 French window latch, *L. H.*
W36 Extension bolt.
W37 Wire hook and eye.
W38 Sash lock.
W39 " cord.
W40 " weights.
W41 " sockets.
W42 " hook.
W50 Blind hinges.
W51 " hold-backs.
W52 " catches.
W53 " adjuster.

Miscellaneous Hardware

- M60* Towel hooks.
M61 Coat hooks.
M62 Wardrobe hooks.
M63 Wire closet hooks.
M64 Knee-catches.
M65 Cupboard spring catches.
M66 Drawer-pulls.
M67 Loose-pin butts, with tips, 3 in. x 3 in.
M68 Fast-pin " no " 2 in. x 2 in.
M69 Toilet-paper holder.
M70 Pivot for flour-box (1 pair).
M71 Chain to hold drop-front drawers.
M72 Flush-ring cupboard catch.

Quantity Sheet, Door Hardware

	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12	D 13	D 14	D 15	D 16	D 17	D 18	D 19	D 20	D 21	D 22	D 23	D 24
1.....			3								1			1										
2.....			3			1								1										
3.....			3												1								1	
4.....					2												1							
5.....			3							1				1										
101.....				3				1								1		1						1
102.....				3				1								1		1						
103.....				3			1									1								
104.....				3		1										1								
105.....													1					1						
106.....				3		1										1								
107.....				3						1						1		1						
108.....				3			1									1								
109.....				3			1								1									
110.....				3								1				1								
111.....				3								1				1								
112.....				3			1							1		1								
113.....																					1	2		
114.....				3								1			1									
115.....				3							1				1									
116.....				3			1							1		1								
117.....				3								1			1									
118.....					1															1				
201.....				3								1				1					Pair			
202.....				3								1				1								
203.....				3						1						1								
204.....				3					1							1								
205.....				3								1				1								
206.....				3					1							1								
207.....				3					1							1								
208.....				3						1						1								
209.....				3							1					1								
210.....				3								1				1								
211.....				3						1						1								
212.....				3							1					1								
213.....				3						1						1								
214.....				3					1							1								
215.....				3								1				1								
216.....				3									1			1								
301.....				3							1			1										
302.....				3								1		1										
	93	18	3	4	4	2	5	4	6	11	1	11	1	25	1	3	1	1	1	2	1	1		

Quantity Sheet, Window Hardware

	W 30	W 31	W 32	W 33	W 34	W 35	W 36	W 37	W 38	W 39	W 40	W 41	W 42			W 50	W 51	W 52	W 53
51	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
52	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
53	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
54	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
55	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
56	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
57	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
58	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
59	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
60	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
61	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
62	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
150	..	..	..	No Hardware	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
151	..	..	..	No Hardware	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
152	..	..	..	No Hardware	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
153	..	..	..	No Hardware	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
154	Pairs	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
155	..	..	..	..	6	1	2	..	..	..	..	..	..	..	..	3	2	2	1
156	..	..	..	..	6	1	2	..	..	..	..	..	..	..	..	3	2	2	1
157	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
158	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
159	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	3	2	2	..
160	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
161	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
162	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
163	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
164	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
165	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
166	..	4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
167	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
168	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
169	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
170	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
250	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
251	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
252	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
253	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
254	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
255	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
256	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
257	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
258	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
259	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
260	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
261	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
262	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
263	..	4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
351	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
352	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
353	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
354	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
355	..	4	..	..	..	..	..	..	1	15	4	1	..	..	..	..	..	..	..
356	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
357	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
358	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
	10	166	54	10	12	2	4	10	39	585	156	21	1	..	..	69	46	46	22

Quantity Sheet, Miscellaneous Hardware

	M60	M61	M62	M63	M64	M65	M66	M67	M68	M69	M70	M71	M72
90			4							1			
91	3			12									
190					1	1	3	2					
191					1	1		2					
192					1	1	3	2					
193					1	1	3	2					
194					2	2		4					
195					1	1	4	2			1		
290	4		6							1			
291							3						
292				24									
293		2		30									
294		2		30									
295													
296		2		30									
297		2		30									
	7	8	10	156	7	7	16	14	3	2	1	90	3

Based on the foregoing memoranda and quantity sheets, we are now prepared to make out a list covering every detail of hardware required, and to submit same for quotation of prices. This list, with prices quoted as current in September, 1907, for *cheap*, *medium*, and *best* grades of hardware will assume substantially the form of one of the following bills:

BILL No. 1

Bill for the Cheapest Grade of Hardware which under any Conditions would be Suitable

DOORS

		PRICE
D3	93, 4x4 in. wrought-iron japanned loose-pin butts, 5 knuckles, with tips on pins; 47 pairs.....@ \$0.18....	\$ 8.46
D4	18, 5x5 in. butts, same as above; 9 pairs.....@ .30....	2.70
D5	3 Pairs 14 in. plain tee-hinges.....@ .20....	.60
D6	4 R. H. plain knob latches, brass front, and strike-plate, all interior works of brass or bronze.....@ .80....	3.20
D7	4 L. H. latches same as above.....@ .80....	3.20
D8	2 R. H. cylinder latches with flat pass key and stop-work (works same as above).....@ 4.00....	8.00
D9	5 R. H. latches with thumb-bolt (works same as above).....@ 1.00....	5.00
D10	4 L. H. latches with thumb-bolt (works same as above).....@ 1.00....	4.00

HARDWARE

55

D11	6 R. H. latches, dead-bolt, with three tumblers and bit key (works same as above).....@	1.00....	6.00
D12	11 L. H. latches, dead-bolt, with three tumblers and bit key (works same as above)	@ 1.00	11.00
D13	1 Sliding-door latch, all brass or bronze except case		2.15
D14	11 Mineral door-knobs, round, iron escutcheons, common spindles.....@	.10....	1.10
D15	1 Heavy japanned iron store-door latch with thumb-piece.....		.20
D16	25 Pairs jet knobs, with 23 pairs plain bronze-plated escutcheons approximately 1½x5½ in. @ 34c... and 2 pairs solid bronze similar escutcheons, 1 pair for front vestibule door, and 1 only for outside of 2nd vestibule door and back hall door @ 81c.....	7.82 1.62....	9.44
D17	1 2½-in. Padlock and hasp, all iron except interior of padlock, which is to be of brass and to have three tumblers; also chain for securing padlock when not in use.....		.40
D18	3 Chain-bolts, plain wrought iron, bronze-plated...@	.60....	1.80
D19	1 Set sliding-door hanger and track, with 5-in. iron anti-friction wheels.....		4.00
D20	1 Refrigerator clamp, cast-iron galvanized, 6-in. lever handle with 6-in. bolt.....		.40
D21	1 Pair 6-in. japanned iron double-acting spring butts		1.75
D22	2 Push-plates approximately 3x12 in., wrought-iron, bronze-plated.....@	.40....	.80
D23	1 Heavy iron 6-in. bolt.....		.15
D24	1 Solid bronze, plain electric bell push-button.....		.20

Total cost for doors.....\$ 74.55

WINDOWS

W30	10 Pairs 3x3 in. fast-pin plain iron butts.....@	\$0.06½...\$	.65
W31	156 Window pulleys, wheel 2-in. on running face, steel pin and bushing, wheel and face iron, 13 doz.....@	1.00....	13.00
W32	54 Hook-pattern sash-lifts at least 1½x1½ in. bronze-plated iron, 4½ doz	@ .28....	1.26
W33	10 Heavy cellar-window fasteners, combined with pull, japanned iron.....@	.08....	.80
W34	6 Pairs 5x5 in. loose-pin butts (same as D 4).....@	.30....	1.80
W35	2 L. H. French window latches with lever handle (similar throughout to No. 7, except that in depth they are to be no more than 1½ in.).....@	.60....	1.20
W36	4 Flush bolts with knob or lever operating device, 12 in. long, bolt ¾ in. in diameter, all visible parts iron, bronze-plated.....@	.40....	1.60

W37	10	Wire hooks and eyes, 4 in. long, wire not less than $\frac{1}{8}$ in. in diameter (No. 11 gauge).....@	.02....	.20
W38	39	Sash-locks, approximately $2\frac{1}{2} \times 2\frac{1}{2}$ in., iron, japanned, with horizontal action and of such design that sash will be drawn $\frac{1}{2}$ in., $3\frac{1}{2}$ doz.....@	1.00....	3.25
W39	600	feet $\frac{1}{2}$ in. braided (white) cotton sash-cord, 13 lbs.@	.30....	3.90
W40	156	Sash-weights (iron), approximately 1,800 lbs.....@	.01 $\frac{1}{2}$ *..	31.50
W41	21	Flush sash-sockets, 1 in. diameter, iron, $1\frac{1}{2}$ doz...@	.25....	.44
W42	4	Pull-down hooks, bronzed iron, mounted on poles 5 feet long.....@	.40....	1.60
W50	69	Pairs wrought-iron blind hinges.....@	.09....	6.21
W51	46	Wrought-iron blind fasteners, $3\frac{1}{2}$ doz.....@	.50....	1.92
W52	46	Iron blind catches for sill, $3\frac{1}{2}$ doz.....@	.12....	.46
W53	22	Sets blind adjusters,** rods not less than $\frac{1}{8}$ in. in diameter, which will hold the blind open at any angle up to 60° from the house, $1\frac{1}{2}$ doz.....	3.50	6.42
Total cost for windows				\$ 76.21

MISCELLANEOUS HARDWARE

M60	7	Towel hooks, japanned iron, projection 6 in. .@	\$0.15....	\$ 1.05
M61	8	Coat " " " " 6 in... @	.15....	1.20
M62	10	Wardrobe " " " " $3\frac{1}{2}$ in...@	.03....	.30
M63	156	Wire closet hooks, $1\frac{1}{2}$ gross.....@	.90....	.98
M64	7	Knee-catches, iron, japanned, plate on door approximately 1x2 in.....@	.06 $\frac{1}{2}$	.44
M65	7	Cupboard spring catches round or T-handles, base not less than 2x2 in., japanned iron.....@	.25....	1.75
M66	16	Plain iron drawer-pulls, japanned, not less than 4 in. long, one to be used on each drawer, also one on flour-box, $1\frac{1}{2}$ doz.....@	.40....	.54
M67	14	Pairs 3x3 in. loose-pin butts with tips, japanned iron, 2 to each cupboard door.....@	.08....	1.12
M68	3	Pairs 2x2 in. fast-pin butts, iron (drop-front drawers).....@	.05....	.15
M69	2	Toilet-paper holders, nickel-plated, to hold rolled paper, and of heavy plain pattern.....@	.30....	.60
M70	1	Pair heavy iron pivots for flour-box.....@	.15....	.15
M71	9	feet of light brass chain, for holding in horizontal position drop fronts of drawers.....@	.01 $\frac{1}{2}$	.14
M72	3	Flush-ring cupboard catches for closing drop fronts to drawers.....@	.30....	.90
Total cost for Miscellaneous Items.....				\$9.32

* NOTE.—The price of sash-weights varies materially in different localities, depending on local facilities for casting them.

** NOTE.—If of a type combining sill catch for securing blinds when shut, W53 can be dispensed with; but under any circumstances W51 will be required.

Summary

Hardware for Doors	\$ 74.55
" " Windows	76.21
" " Miscellaneous Items	9.32

Total cost for cheapest grade of hardware suitable.....\$160.08

The hardware items listed in the above bill are all of a substantial character, but of such grade that at no point is money expended for the sake of appearances. The total cost, \$160.08, is certainly a very low amount to expend for hardware in a home of this character. In several points, accordingly, changes from the above list can be made with advantage, as follows:

BILL No. 2**Hardware of Middle Grade in Every Respect Suitable****DOORS**

D3	All butts for second story changed to a good quality bronze-plated butts, making these items:		
	35 Pairs, unchanged	@ \$0.18....	\$ 6.30
	12 Pairs, changed	@ .43....	5.16
D4	9 Pairs, changed to finish as above	@ .57....	5.13
D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15,	price unchanged		44.45
D16	23 Pairs of jet knobs changed to spun or wrought metal, escutcheons not changed but with screwless spindles	@ .86....	19.78
	2 Pairs changed to cast bronze knobs to go with bronze escutcheons (outside doors)	@ 1.50....	3.00
D17, D18, D19, D20, D21,	unchanged		8.35
D22	Bronze push-plates in lieu of bronzed iron (for wearing qualities only), 2	@ .60....	1.20
D23	Unchanged		.15
D24	One solid bronze electric bell push-button with face-plate 2 in. x 4 in.		.50
Total cost for Doors			\$ 94.02

WINDOWS

W30, W31, W32, W33,	unchanged		\$ 15.71
W34	Changed same as D4, 6 prs	@ \$0.57..	3.42
W35	Unchanged		1.20
W36	Flush-bolts changed to bronze, 4	@ 1.35....	5.40
W37, W38, W39, W40,	unchanged		38.85
W41	21 Sash sockets changed, 1 in. x 2 in. bronzed iron ..	@ .50 doz.	.88
W42, W50, W51, W52, W53,	unchanged		16.61
Total cost for Windows			\$ 82.07

MISCELLANEOUS HARDWARE

M60, M61, M62, M63, M64, unchanged.....		\$ 3.97
M65 7 Cupboard spring catches, changed to bronzed iron (same price as japanned),.....@ .25....	1.75	
M66 16 Drawer-pulls, changed to bronze-plated.....@ .60 doz.	.80	
M67 14 Pairs 3 in. x 3 in. loose-pin butts, changed to bronze-plated.....@ .18	2.52	
M68, M69, M70, M71, M72, unchanged.....	1.94	
Total Cost for Miscellaneous Items.....		\$ 10.98

Summary

Hardware for Doors.....	\$ 94.02
" " Windows.....	82.07
" " Miscellaneous items.....	10.98

Total cost for hardware of middle grade in every respect suitable.....\$187.07

If it is desired to place the *best hardware* which is in any way suitable for the dwelling under consideration, a bill along the following lines would be made up (not duplicating the detail of the first or second bills where unchanged):

BILL NO. 3

Hardware of Best Grade

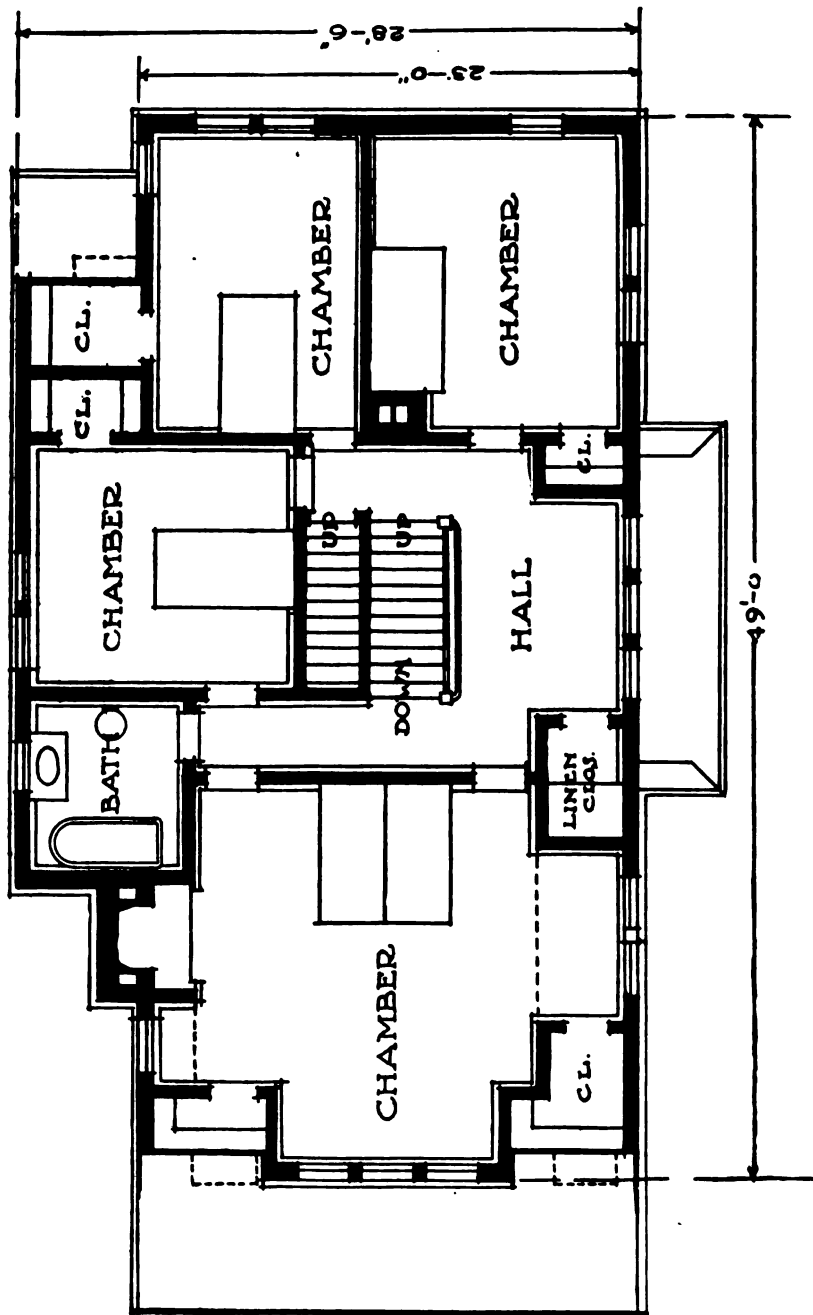
DOORS

D3 All butts in second story changed to the best quality of bronze-plated or wrought-bronze, ball-bearing 12 pairs.....@ \$0.62....	\$ 7.44
Unchanged, 35 pairs.....@ .18....	6.30
D4 9 Pairs changed to finish same as above.....@ .75....	6.75
D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, unchanged.....	44.45
D16 23 Pairs of knobs and escutcheons, changed to cast metal.....@ 1.50....	34.50
2 Pairs not changed from Bill No. 2.....	3.00
D17, D18, Unchanged.....	2.20
D19 One set sliding-door hangers, changed to ball-bearing.....	5.50
D20 One refrigerator clamp, changed to brass.....	.75
D21 One spring double-acting hinge unchanged.....	1.75
D22, D23, D24, unchanged from Bill No. 2.....	1.85
Total Cost for Doors.....	\$114.49

WINDOWS

W30 Unchanged.....	\$ 0.65
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SECOND-FLOOR PLAN, GARDEN CITY COMPETITION, LONG ISLAND, N. Y.

J. Lovell Little, Jr., Architect, Boston, Mass.

For Elevation and First-Story Plan, See Page 98.

HARDWARE

59

W31	156 Window pulleys, changed to bronze face and wheel, roller-bearings, 13 doz.....@	4.60 doz.	59.80
W32	54 Flush bronze sash-lifts, 3 in. x 1½ in.....@	.60 doz	2.70
W33	Same as in Bill No. 1.....		.80
W34	6 Pairs, changed to best-quality bronze-plated or wrought bronze, ball-bearing.....@	.75....	4.50
W35	Unchanged.....		1.20
W36	“ from Bill No. 2.....		5.40
W37	“ “ “ “ 1.....		.20
W38	39 Solid bronze sash-locks, 3½ doz.....@	4.00....	13.00
W39	600 Feet sash chain in lieu of cotton cord.....@	.02½....	13.50
W40	Unchanged from Bill No. 1.....		31.50
W41	21 Sash sockets, same as in Bill No. 2.....		.88
W42	4 Bronze pull-down hooks polished poles.....@	1.00....	4.00
W50, W51, W52, W53,	unchanged.....		15.01
Total Cost for Windows.....			\$153.14

MISCELLANEOUS HARDWARE

M60, M61, M62, M63, M64, M65, M66, M67, M68, M69, M70, M71, M72, unchanged from Bill No. 2.....	\$10.98
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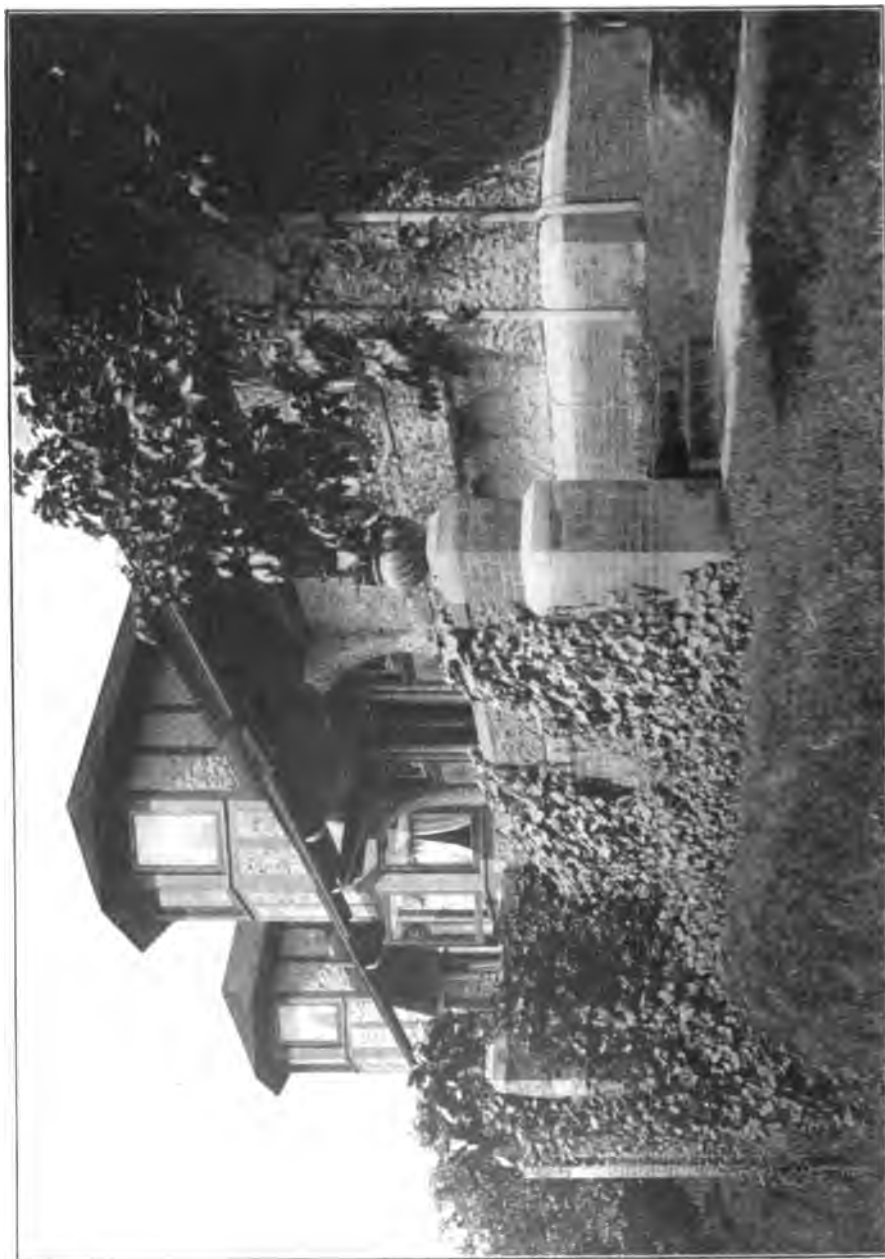
Summary

Hardware for Doors.....	\$114	49
“ “ Windows	153	14
“ “ Miscellaneous Items.....	10	98
Total Cost for Hardware of Best Grade...		\$278.61

By comparing the figures of these three bills, it will be seen that the price varies as follows:

Bill No. 1—Very plain but thoroughly substantial hardware.....	\$160.08
Bill No. 2—Varying from the above by using more ornamental fixtures.....	187.07
Bill No. 3—By using the best material and appliances appropriate.....	278.61

Attention is very particularly directed to the fact that none of the bills call for designs with other than *plain surfaces*. For general use, where the best results from all points are desired, the scheme on which Bill No. 2 is based is by far the best. Few persons would ever notice a difference between schemes No. 2 and No. 3, although the latter costs nearly 50 per cent more than the former.



HOUSE AT PARKERSBURG, W. VA.

R. C. Spencer, Jr., Architect, Chicago, Ill.

Red Brick for Water Tables. Rough Cast Finish on Metal Lath on Mud Plaster above Water Table. Windwork in Unfinished.

PLASTERING

The subject of plastering in relation to modern dwellings is necessarily divided into two sections. The first treats of the plastering of walls on the *interior* of the house; the second will briefly describe some of the various ways of finishing in cement plaster the house *exterior*.

INTERIOR PLASTERING

The installation of interior plastering marks the division between the completion of the *rough work* on the residence, and the very beginning of the placing of the *finish* that is to follow.

The plastering cannot be started until the walls and ceilings have been lathed, and the ceilings must be furred before even the lathing can be begun. When the building is ready for lathing, all of the rough studding, framework, and partitions must be set in place; and the piping and wiring necessary in the plumbing, heating, lighting, etc., of the dwelling, must be installed and tested before the lathing or furring can be started.

The apparent break in the progress of building necessary to lath, plaster, and dry out a house, need not be altogether time lost for any of the various trades. Those unable to resume work until this intermediary process has been completed, can be securing their necessary materials and fixtures and arranging them ready for installation. The carpenter can be getting out his mill work and finish, be ready to put in his window-sash, set his standing finish in place around doors and windows, lay the upper floors, etc., and complete the remainder of his contract. The painter and paperer then commence their work; the electricians, plumbers, and heating contractors install their service fixtures, and the dwelling is soon ready for occupation.

The studs of a building are spaced sixteen inches apart on centers, so that each lath receives four nailings. Each end of the lath rests upon the center of a stud; and the two intermediate studs provide fastenings at spaces equally distant in its length. The ceilings are

customarily furred to provide lath nailings, four—and in better work, five—nailings to the lath, with furrings seven-eighths of an inch thick and one and one-quarter inches or more wide, running crosswise of the floor joists. This furring is intended to level up the bottom of the joists, and distributes the unequal result of their shrinkage or uneven settlement from the weight above, thus preventing plaster cracks.

Before beginning lathing, the carpenter should see that each partition, at its intersection with another wall, is started with a stud nailed directly against the crossing studding. This makes it impossible for the lather to run the ends of his laths in behind or over the partitions—a careless practice that provides a very unstable internal plaster angle. The carpenter also sets plaster furrings, three-quarters of an inch thick, around all window and door openings and around the walls at the height of the top of his base skirting, so as to mark the points where the work of both plasterer and lather end, and to provide nailings for the finish woodwork. It is essential for the carpenter to place any necessary furring for cornices, door-caps, etc., before the lathing is begun; also any other furring blocks that may be required by the plumber to secure the setting of his fixtures or to support and carry his pipes.

LATHING

Wood Laths. Wood laths are put up in bundles of 100 laths; and are nailed upon the studdings of the wooden frame, with a space of one-quarter inch between them. This distance is sufficient to allow for lath shrinkage or swelling, and still provide a firm clinch for the plastering. If the space is much less than this, the plaster clinch will be weakened. If much more, the laths may possibly sag down on the ceilings with the extra weight of plaster. In no instance should these spaces between laths exceed a width of three-eighths of an inch.

The *clinch*, or *key*, of the plaster is formed by the mortar being pressed through the spaces between the laths and then spreading out back of the laths upon both sides of the crack, so forming a tie, or clinch, that holds the mortar firmly and securely in place.

It occasionally becomes necessary to lath on very thin furrings to cover over a heating pipe, a brick or iron support, or some other such exceptional instance of construction. In that case a wider space

between the laths may strengthen the plaster clinch; or, better still, a strip of expanded metal may be used over or around such obstructions.

The best wooden laths are made of pine or spruce, and are only partially seasoned. They should be free from sap, bark, and dead knots. Both bark and knots are likely to loosen from the surrounding wood and so destroy the hold of the plaster; while the face of the plaster is occasionally stained from pitchy knotholes, bark, or sap. All laths are now machine-sawn. The old-fashioned split lath has not been in the market for now more than fifty years.

If the laths are too dry, the wet mortar is likely to cause them to warp and twist; and if it hardens or sets before the laths become saturated, their swelling is likely to produce parallel plaster cracks. Better results can be obtained by using wet laths, when both mortar and laths dry out together.

In specifying the nailing of wood laths, it is sometimes thought to ensure better work if two nailings are required at each end of the lath, either upon the ceiling alone or upon both wall and ceiling. It is more than doubtful if this requirement produces the desired result, as two nails in the lath end are likely to start a split, which may be increased by the pressure necessary in applying the mortar, until the entire end of the lath is partially or wholly loosened from its support before the plastering is all upon the wall. Large lath nails, instead of making the work more secure, weaken it in the same way. The common-sized inch-and-one-eighth long—"three-penny fine"—nails fasten the laths securely, even the ceiling nails rarely pulling out. About five pounds of nails will be necessary to each one thousand laths.

The joints of laths are ordinarily broken every eight courses. This means that not more than eight adjoining lath ends are nailed upon one stud or furring, the next eight laths, in both directions, being carried by, ending upon the next wall stud or ceiling furring to either right or left, thus alternating the break and obviating the possibility of an extended crack occurring at the line of lath jointure. Some lathers find a small handful of these laths more convenient to handle than a larger bundle, in which case it is simpler and easier for them to break joints every six laths—which is equally good construction. Occasionally studding is placed twelve inches apart, and the lath joints broken for every other lath. Such precautions, however, are

not necessary in the ordinary dwelling. They increase expense; and the closer spacing of the studs, especially, provides more undesirable weight to be carried by the house frame.

Wherever the wood studding of partitions comes up against the brickwork of chimneys or a terra-cotta or brick wall, strips of expanded metal or wire-mesh lath should be employed, extending seven or eight inches over upon either side of such a joint; and, if such a joint occurs in an internal angle, future cracking from a difference in settlement or shrinkage may be prevented by cutting through each plaster coat, when soft, with a sharp trowel.

Metal Lath. Of late years many varieties of metal lath have been placed upon the market. The use of such lath is generally required on boiler-room ceilings, and in other places exposed to strong artificial heat. Many varieties of metal lath—including all those made of wire—require supports at closer intervals than is provided by the studding, nine inches being generally considered the best distance. This necessitates either a closer spacing of studs than is otherwise necessary or desirable, or a series of furrings fastened to the wall studding.

There are some metal laths—generally those made on the expanded principle—that are sufficiently stiff, in one direction, to allow of a spacing of supports greater than nine inches; but, for ordinary wire cloth, no wider distance should ever be allowed, unless the cloth is itself artificially stiffened. All metal lath should be securely fastened by staples, and stretched before nailing, to increase its stiffness as much as possible.

In using metal lath, care should be taken to prevent plaster cracks along the line of jointure. The use of metal lath also requires three coats of plaster, in order to stiffen the lath sufficiently to resist the pressure required to finish the last coat.

Lathing and plastering are generally estimated, and the various materials are all figured, by the square yard. In small work, no openings are deducted unless they exceed sixty square feet in area. In figuring up plaster by quantity, when openings are allowed for, it is sometimes customary to add half of the contents when measuring closets; while small triangular wall pieces are figured as though square, in order to make up for the extra amount of labor required in plastering such restricted or odd-sized surfaces.

The use of expanded metal or wire lath is frequently demanded

by the building laws of some cities, and is always required on a fire-proof or first-class building.

Several makes of *plaster board* are in the market and being extensively advertised. They come in eight inch wide boards or large sheets of 32 by 36 inches, and are nailed directly upon the wall framing. One coat of plaster—in three-coat work—may then be dispensed with. These boards save time, being rapidly set in place even by unskilled carpenters, and the plaster itself dries out much more rapidly. They are, however, frequently the cause of cracks that appear in the finished plaster where the edges of the boards come together—sometimes even after the wall has been papered.

PLASTER MATERIALS

Plaster is principally composed of *lime, sand, hair, and water*.

Lime is obtained in different sections of the country from calcined limestone, the carbonic acid and moisture contained in the stone being driven off by the burning process. The whole theory of plastering is based upon the reduction of limestone to lime, and its chemical recombination, when distributed upon the walls of a house, into something approaching its original state. The *slaking* of the lime provides the moisture necessary for the process of crystallization that produces the *set* of the mortar; while the sole purpose of applying it upon the wall in several coats is to present that much more surface to absorb the carbonic acid—of which it was originally deprived in burning—from the air. The thinner the coats and the larger their total exposed surface, the greater the absorption of this strengthening constituent. For this reason—and solely for this reason—is three-coat plaster work to be considered as better than two.

Properly burnt lime slakes easily and completely, when water is added, until it is converted into a fine dust, which, in its turn, is moistened and turned into a paste under action of the water, which bubbles and hisses with the heat generated by the process. This is what is called the *slaking* of lime. Very rich and pure lime—the best for plastering—increases to about twice its original bulk by being slaked, and is then almost pure white in color. Lime should always be as fresh as possible, and must be delivered in tightly sealed barrels. Care should also be taken to ascertain that it has been burned with wood and not with coal.

Sand is broken or rotten rock which has become decomposed spontaneously or by the action of running water. That made by running water, or from stones worn small by rolling over and over upon the beach, is composed of particles so nearly round in contour and so lacking in angularities of surface that they are not good material for mixing in any mortar where *strength* is a requisite or necessity. The particles of rotten rock decomposed by exposure are better adapted to make good sand for mixing with mortar, their shape being more irregular, with many sharp and angular corners. Sand obtained from ledge stones contains the essential elements of those stones, quartz, feldspar, and mica being present in granite formations, and lava, obsidian, etc., in volcanic sand. The sand coming from the softer stones is generally more thoroughly disintegrated, being frequently so rotten as to be entirely unsuitable for use in plastering. In most parts of the country the principal supply of sand now comes from the beds of ancient lakes or rivers, and is called *pit sand*. True sand, no matter how fine, may always be distinguished from dust by dropping it into a glass of water, as it will invariably sink to the bottom without leaving any appreciable dirt upon the surface.

For plastering purposes, sharply angular sand is not absolutely essential. Good river sand, the coarser the better, is obtained so easily, and is so clean and free from dirt, clay, and earth stains, that it is most generally employed for plaster.

The third necessary constituent is *hair*. The best hair upon the market is cattle hair obtained from the tanneries. The hair should be of good length; and, if too lumpy or clotted, it should be separated by soaking in water the day before mixing it with the mortar, as this method of separating the hair is less dusty and more healthful than beating or whipping it dry to obtain the same result.

Occasionally brick dust is added to the mortar for coloring, when it is likely that the mortar will set more rapidly—especially if the dust is mixed in shortly before using and is dry at the time of mixing. All brick dust should be sifted through a fine sieve. Besides brick dust, a variety of colorings for mortar are used—such as lampblack, ivory black, powdered charcoal, Spanish brown, raw umber, burnt umber, red aniline, Venetian red, Indian red, vermilion, ultramarine blue, indigo blue, chrome yellow, and, occasionally, pulverized clay. Mineral colors should be preferred to earth colorings. The latter

weaken the plaster, and fade rapidly. Various colored sands—when they can be obtained—make the best and most durable materials possible for tinting the final plaster coat.

It is impossible to state arbitrary, set, hard-and-fast proportions for the mixing of plastering for either exterior or interior work. The different makes of lime and grades of sand, alone, vary sufficiently to make any such statements exceedingly inadvisable; while the purpose and conditions under which the plaster is to be used, frequently occasion considerable changes in its proportions.

“Working” the Lime. The first process in the making of plaster is the *slaking* of the lime. This consists, as already said, in simply reducing the hard, brittle lumps of its original form to a smooth paste by mixing it with water. It is of the utmost importance that the lime should be entirely and completely slaked, and the paste smoothly and evenly *worked*, before adding any of the other ingredients.

The lime is slaked in a *mortar-bed*, a box of boards about 4 feet wide and 7 feet long, and a foot to eighteen inches high, set in some convenient location with its bottom about level with the top of a second box placed at one end, and about two feet lower in grade. Both mortar and lime-slaking beds should have tight bottoms and strong sides, well braced to resist the pressure that will come upon them when they are full. A quantity of sand already screened should also be near at hand. Poorly screened sand later causes extra trouble and work. Gravel in the mortar delays workmen while plastering and floating, and much good plaster material will be lost in hurriedly throwing or picking out these gravel stones in the rush of applying the mortar on the wall.

The barrel lime is emptied into the upper box, and water is poured on while a workman breaks up the lumps and works the mass back and forth in various directions with a hoe. The thorough working of the material at this stage is necessary to ensure its complete slaking. The tendency of the careless workman is to hoe back and forth in the center of the bed without any regard as to whether he is stirring up the mortar that is down on the bottom boards, or whether the corners are drawn into the mixture and worked as evenly as the remainder of the box. If the paste is not thoroughly and evenly worked to an equal consistency throughout, if the water is not conducted to every particle of lime, or if the other ingredients are mixed in before the paste is

evenly prepared, the lime will be apt to *blister* and slake out unevenly, causing trouble after it is upon the wall. If the corners, for instance, are imperfectly mixed, lumps of clear lime will afterward appear. Many of these lumps will pass unnoticed under the hoe of the workman tempering the mortar, and will not be found until they are flattened out under the wall trowel of the plasterer.

If too much water is used in slaking the lime—especially if a too great amount is added at once—the pile is *chilled* and forms into lumps that slake too tardily. If too little water is added, the lime is left so dry (*burns*, as the plasterers call it) that many small particles entirely fail to slake through lack of sufficient moisture. When too much water *drowns* the lime in the first place, it becomes so thoroughly chilled that a considerable portion of its strength is lost; and the process of slaking is, by the very excess of water, much retarded. The process is also slowed up if very cold water is added, although the water soon becomes heated from the reaction of the lime. At the start, just enough water should be put on to initiate the slaking process. After this, as the slaking proceeds, more water should be added as needed, taking care to keep the lime thoroughly moist at all times. A very active and quick slaking lime should be covered with water from the very beginning, to guard against the possibility of burning. If the lime once *burns*, it will afterward be impossible, by any amount of working, to get out all the fine lumps that are then caused. Rich lime will afterwards work cool, is little likely to crack, and bears troweling when being finished, without the surface peeling off, blistering, or staining.

If lumps of unslaked lime escape through the screen when the lime is run off, and get mixed into the mortar, it becomes very difficult to eradicate them afterward. It is not possible for the plasterer to get these lumps out of the mortar when working it on the wall; and the results of their afterwards slaking out will continue to appear long after the house is finished. If they occur in the first coat, at various times after the work is completed—frequently extending throughout the entire first year—these lime lumps will suddenly *blow* or expand, forcing out the surface plastering outside them and making a large blister or lump, generally about an inch in diameter, which, if upon the ceiling, almost invariably falls off. If this unslaked lime gets into the final coat, much the same result occurs, although the particles

are of necessity smaller in size. Instead of being large, the resulting holes are then comparatively small, running generally about the size of the head of a pin, and the entire surface of the plastering is frequently pitted, the particles thrown off appearing about the room in the shape of a white dust.

In the brown rough-coat, the spots of white, unslaked lime are quite easy to see, as they are often the size of a bean or pea. However, in the final white coat, these spots, being smaller and of the same color as the rest of the mortar, do not show.

After it has once begun to warm up, the lime should be worked or stirred thoroughly during the process of slaking, so that, after the action has been completed, it will be of the consistency of a pasty cream. After slaking, the lime should be run off through a fine sieve (No. 5 screen) put at the end of the slaking box, into the next lower compartment, or mortar-bed. The screen is intended to keep out any lime lumps too large to slake before the mortar is used, or any flinty settlement that may be found in the lime, and to allow only a pure and thoroughly mixed hydrate to be admitted to the bed.

When drawing or running off the lime, a large supply of sand already screened should be at hand to scatter in the bottom of the mortar-bed and to use for stopping leaks that may appear as the box gradually fills. This screened sand should be sufficient in amount to complete the mortar mixture. An ample supply of water, either in barrels or in hose piped from a hydrant, should also be ready at hand—to avoid any possibility of the lime burning.

For the *putty* or *finish coat*, the paste should be made even thinner before running off, and may be of the consistency of milk. The sieve through which it is strained should also be finer, of about the mesh of an ordinary flour or meal screen. The paste for this coat is often obtained by running off the lime a second time, as by this means a cooler working putty is secured.

The length of time that mortar for plastering should be mixed before being used, is a much-discussed question. It is generally stated in architectural specifications, that “the mortar should be mixed ten days or two weeks before using.” As a matter of fact, this requirement is not always either wise or desirable. It is true that, in old English work, lime mortar was left covered over with earth to stand for long periods of time, often six months to three years elapsing

before it was used. In this country, such slow-going methods are not to be expected. While lime does gain in strength by standing in this thin putty state before sand or other materials have been mixed with it, yet three or four weeks, at the least, are necessary before the increase becomes very apparent. It is also necessary that the paste should remain moist, by being kept covered all the time. At the end of the fourth month its strength will have increased about one-fifth, and most of this gain has been made during that month. From then on the gain continues, but gradually decreases in amount.

It is more economical for the plasterer to use a lime that has been slaked for some weeks, as, when tempered down, it will work freely with the admixture of a much larger proportion of sand than is taken up by lime mixed as soon as it can be readily worked. This extra amount of sand does not add to the strength of the mortar; but, as it causes the lime to cover a greater surface, it is a considerable economy for the contractor, made, however, at the expense of the quality of his work.

Lime mortar need be left standing only long enough for all its particles to be thoroughly slaked, and, if properly mixed and wet down in the first case, a great deal of time need not be required to effect that result. This once secured, the quicker the mortar is mixed and put upon the building, the better and stronger will be the plastering that is obtained. It is further claimed that the accompanying loss of limewater is also very harmful, as this water—from the properties which it has already absorbed from the lime—is much better suited for carrying on the process of mixing than newly added clean water. Yet, if the lime has been long standing, it may be necessary to add clean water to replace the water lost by evaporation or seepage, although mortar mixed with clean water never becomes so hard as that mixed with the water obtained in slaking the lime.

The sand and hair are next added, the hair being put in before the mortar becomes too stiff to work readily. After the sand is mixed, the mortar should not be left to stand for any length of time, as it would become considerably *set* and a loss of strength would result. If the mortar does become set in the bed, reworking would be necessary before it could be put upon the walls. The strength then lost bears a direct relation to the length of time it has stood, and the solidity it has attained, before this final working up.

In plastering mortar where hair is required, a still further loss of strength would result, as the hair would be so rotted or eaten by its long exposure to the action of the wet lime as to be almost or quite worthless. The hair cannot well be mixed evenly, except at the time when the mortar is first run off, while it is in a very thin paste. If, after a lime-and-sand mixture had been standing for some months, it were attempted to bring it to a sufficiently fluid state to receive the hair properly, by wetting it down a second time, a considerable proportion—varying from a quarter up to almost a half—of its strength would be sacrificed.

Bearing these facts in mind—once certain that the lime is slaked—it would appear better that not more than a week should elapse before the use of this mortar; and a less time than that is, under many circumstances, undoubtedly desirable. It is evident that no more lime-and-sand mortar should be mixed at one time than can be used within a few days at the most. The length of time that mortar should be allowed to stand, is determined more or less by the dryness or moisture of the atmosphere. The dryer the atmosphere, the shorter the time, as the setting of the mortar is, in part, a chemical result of the drying out, or evaporation, of the *water of crystallization*, as it is called.

It has already been said that limes made in different parts of the country vary extensively in their chemical composition and properties. A knowledge of the chemical composition of lime mortars and the individual peculiarities of the lime locally used, is necessary before applying or attempting to utilize the principles here set forth. In the eastern part of the United States, the limes frequently contain from a third to a half of carbonate of magnesia; and the mortar in which such limes are employed sets very readily.

To sum up, the lime should be slaked as evenly and thoroughly as possible. It should be run off from the slaking bed through a fine sieve into the mortar-bed. It should lie there no longer than is absolutely necessary; and if it could be possible to add the hair and sand while the original mixture is sufficiently moist to take up and work the entire amount of the latter material to be added, the resulting mixture would undoubtedly be that much the stronger and more durable.

Mixing the Mortar. The amount of sand to be mixed in with the lime paste is a variable quantity, depending upon the sand itself,

upon the quality and thickness of the lime paste, and also upon the nature of the work for which the mortar is intended. With exceptionally rich limes, sand to the amount of about two times the bulk of the lime—measuring the slaked lime in the form of a rather firm paste—may be added. As will be seen, this is a most uncertain proportion, for a great deal depends upon the firmness of the lime paste alone. Allowing for variation in size of the lumps of lime and their closer or looser packing together, it may perhaps be better to say that the sand should bear a relation to the lime, before it is slaked, of from three to four and one-half times its bulk.

The richer the lime and the finer the particles of sand, the more of the latter should be employed, although the finer sand does not make as hard or as good mortar as the coarser variety. If both are clean and sharp, the finer and coarser varieties of sand may be mixed together with good results. Most laborers are apt to stop adding sand, merely because the mortar mixture becomes hard to work when the paste becomes too thick. This is poor policy, inasmuch as the mixture becomes much harder to work when the tempering is partly completed, a day or two later.

The fineness of the sand is an important factor. A rather coarse as well as sharp sand is considered best, as the amount and capacity of the voids left in such a mixture would be of such size as, without any doubt, would provide space to contain lime sufficient to cement this granular mass very firmly together. The close pressure and contact of the sand particles would also lessen the possibility of settlement or shrinkage, with accompanying *map-cracks*. The hair may be mixed in either before the adding of the sand or when but a very small proportion of the latter has been worked into the lime mixture. The hair is generally mixed with the mortar by means of an iron rake. It should be thoroughly mixed, and enough should be used to make it impossible to find any small sections of the mortar in which the hair cannot be seen. This will require from one and one-half to two bushels of hair to a cask of lime.

If the mortar is to be used as a first coat on stone, brick, or similar surfaces, it will carry more sand, and hair is not considered so essential. a half-bushel to the barrel of lime being generally ample. If too little sand is used, the plaster is liable to dry too quickly when setting, and, after it is dry, will crumble very easily, showing up too white, or ashy

gray, in appearance. If too much sand has been used, the plastering is liable to fall off, and will crumble when rubbed between the fingers.

Mortar for a second coat on lath may be of about this same consistency of mixture. For the final coat (the *putty* coat or *hard finish*) but very little sand is used. The harder the finish, the less the amount of sand. For this coat, the sand is mixed at the time when the putty is run off. For hard finish, when marble dust, brick dust, or anything of that sort is added, it is generally mixed together on the mortar-board immediately before applying. Stucco, or plaster of Paris, is never mixed with putty until immediately before using, on account of its rapid setting, which occurs in a few moments after mixing. When once set before being applied, it becomes useless. No more water than is necessary should be added, either in the mixing of the mortar at first or in its subsequent tempering, as over-much wetting of the lime deprives it of a considerable proportion of its strength, and also retards the setting process by giving that much more moisture that is necessary to be disposed of by evaporation or crystallization.

A bushel of lime is standardized to weigh 80 pounds; 200 pounds is allowed to the barrel; a bushel contains about one and one-quarter cubic feet. A barrel of sand is supposed to contain 3 cubic feet of sand, and a bushel of sand weighs about 120 pounds, and wet mortar 130 or 132 pounds. When hard, mortar is figured to weigh about 110 pounds to the cubic foot.

To summarize—one barrel of lime, 200 pounds, will take about a cubic yard of sand. In most localities a load of sand is supposed to contain twenty-seven cubic feet, or a cubic yard; but it is frequently less than this, extending down to two-thirds of the amount. To the barrel of lime should also be used about two barrels of water and—as we have seen—upwards of two bushels of hair for a first coat. Hair comes in paper bags weighing generally something under eight pounds and containing enough hair to beat up into a measured bushel. This amount of material, when the lime has been slaked and the whole mixed together, will amount to 35 or 40 yards (about 5 barrels) of mortar; and the amount should cover about 40 square yards of lathed area, requiring about 600 laths to surface.

The final skim coat is mixed roughly to the following proportions: A cask of lime to a half-tub of water, which should take up about a

barrel of the hard, clean sand used in the surface coat. Generally the plasterer uses a larger barrel or hogshead for water, than the cask in which the lime is delivered. Also, in some localities, the lime will run somewhat more than 200 pounds to the barrel, Maine lime from Rockland being supposed to average 220 pounds. Rockland lime is considered in the East good lime for scratch and brown coats, but many masons prefer Jacob's lime for the finish coat.

It should be remembered that the bulk of the completed mortar mixture does not equal the total combined bulk of its various ingredients, but is less than the aggregate bulk by about one-quarter.

PLASTERING

Interior plastering is now applied either in two or in three coatings. Three coats are always necessary on metal or wire lath, the first coat being required to stiffen the body of the material sufficiently to allow thorough working of the remaining coats. Even upon wood laths, three coats make a better job of plastering than two. Extra strength and body are obtained by the addition of the extra coat, provided time be allowed to dry out each of the coats thoroughly before the next coating is added. It has now, nevertheless, become the general custom to employ but two coats on the less expensive grades of residence work.

The plaster mortar is applied to the walls with a hand trowel of steel, about four and one-half inches wide by twelve inches long, having a wooden handle that is parallel with the back of the blade. After the mortar is put on and roughly smoothed out with the steel trowel, the *darby*, a long wooden trowel, about four inches wide and three feet in length, is taken by the workman and used—with a scouring motion—to level the plaster surface and work it to an even thickness and uniform density. The flat part of the *darby* is generally of hard pine, a half-inch or slightly more in thickness.

Three-Coat Work. The best interior plaster work always used to be put on in three coats, and was worked to a final thickness of about seven-eighths of an inch. Of the three coatings, the first is the thickest, so that, when dry, it may be strong enough to resist the pressure of working the coat or coats to follow. A large part of the advantage of three-coat plastering is obtained by thoroughly drying each coat out before applying another, thus securing the added dens-

ity and strength made possible by forcing the subsequent coating firmly and strongly against the surface upon which it is being placed. Rubbing or troweling up the rough mortar before it finally dries and sets, also makes it much more compact than is possible from working it at the time when it is first applied.

The first coat, called the *scratch coat*, contains the greatest proportion of hair, that being useful in strengthening the key or clinch of the plaster behind the edges of the wooden laths, through the crevices between which it has been forced. Before this coat thoroughly dries, the surface is *scratched* (hence its name) with a tool designed for that purpose. The surface of the second coat also is sometimes scratched with nails set into a wooden float or darby like that used to rub over the surface, before adding the finish coat. When one coat is entirely dried out before another is applied, this scratching is always necessary, the scratches forming a clinch or tie permitting the subsequent coat to unite the more firmly to the preceding.

The second coat generally contains a larger proportion of sand and much less hair than is necessary in the first coat. The surface of this second coat—or *brown coat*, as it is called—must be brought up true and even, especially at all angles, and be plumb upon the walls. Before the finishing coat is applied, lumps must be removed and all other imperfections corrected, and the mortar must become sufficiently set to allow the entire surface to be rubbed up with a float or darby and so made compact and firm.

To save time, the plasterer adopted the custom of putting his second coat on over the first while the latter was still green. The combined mass (practically one thick coat) was then darbied and treated the same as in two-coat work, over which about the only advantage of this method was in providing a rougher sand surface on the second coat than was possible when more hair (always necessary in first coat) was included. Otherwise, substantially the same results as are secured by thus working two coats together are obtained in the first coat of ordinary two-coat work, at a saving of both labor and time. While this method does not furnish so good or so permanent a job of plastering, it is modernly considered as meeting the requirements of three-coat work, when so specified.

The saving in this sort of three-coat plastering is made chiefly by the plasterer, in the expense of doing his work. The owner pays

more money than a two-coat job would cost him, and actually receives substantially the same grade of work. The second coat, too, dries more slowly when applied before the first coat is dry and hard, and there is therefore not so much saving in time as is generally believed. If three-coat work is attempted at all, it should be insisted that the first coat be thoroughly dry before the second is added.

The final coat is generally composed of lime putty, with a small proportion of white, clean sand, gauged with plaster of Paris. This gives the whitest finished surface. If a color is considered desirable, a colored sand may be used. All lath cracks or settlement cracks occurring in the previous coats should be cut out and patched before the last coat is applied. The final coat is about one-eighth of an inch thick, and the surface is burnished with the steel trowel to an even and straight surface, and worked sufficiently to free it from chip cracks or other surface defects. The lime for the white finish mortar should be run through a sieve of not less than ten meshes to the inch.

From thus combining the first two coats when green, the next step naturally, in the development of methods of work, was to apply but one coat, making it of increased thickness, and scratching it ready to receive the finish skim or white coat, except when it was desirable to finish the plaster with a rough surface, or to *sand-scour* it, as the last process is sometimes called.

Rough Plaster Finish. If the mortar is to be finished with a sand or rough finish, two coats are applied.

The second coat—which should be put on only after the first is thoroughly dry—is substantially the same as the brown coat described above, the rough finish being secured by working the surface of the second coat, before it dries, with a soft-faced float and a mixture of sand with some lime added. Sometimes the surface of the float is of carpet or felt, sometimes of cork or other soft wood. Only so large a surface as may be readily covered at one time, can be floated, darbied, etc., before it has time to set. In this case no hair whatsoever is put in the second coat, as the hair destroys the evenness of the surface that is obtained by the scouring action of the particles of sand rolling around between the surface of the float and the face of the plaster. A long float is generally used for scouring, and the surface is worked to an even and true face, care being taken not to leave any marks from the instrument itself.

While it is generally the custom to add rough plaster finish on the second coat, in inexpensive work, especially for summer residences, a very artistic effect can be obtained by rough-working the surface of the first coat. If one-coat finish is employed, hair must be used, and the consistency of the coat must remain much the same, whether it is surface-finished or not. In that case, however, it is not possible to work the surface as true and as even as the surface of a second coat.

Two-Coat Work. Most plaster work now consists of only two coats.

The brown mortar employed for the first coat should be made of fresh lime used as soon as it is stiff enough to be worked, with strong, well-distributed cattle hair and coarse, clean sand. The first coat of mortar must always be put on with sufficient pressure to force the plaster through between the laths, and so ensure a good clinch. The face of this coat must be made as true and even as possible on surfaces and angles, and plumb on the walls. After the first coat is sufficiently set, it may be worked again with a float consisting of a piece of hard pine about the size of the trowel. Sometimes the face of this float is covered with felt or other material to produce a rough textural treatment on the plaster surface. The first coat should run a strong five-eighths inch in thickness, and should be thoroughly dried out.

It is generally inadvisable to attempt to trowel a two-coat job very smoothly. If the attempt is made to float the first coat when it is too thin or insufficiently set, the instrument is likely to leave marks on the wall, and the plastering is itself likely to crack. It is better to err on the side of caution, as, if the plaster has become slightly too dry, it may easily be dampened by sprinkling water upon it with the plasterer's broad calcimine brush and following it immediately with the float. The use of water in this way has accompanying advantages in that it tends to harden the plastering and to prevent the hairs gathering along the edge of the float, when otherwise they would have to be shaken off every few moments to prevent their rolling under the instrument and being pressed into the surface of the plaster in tufts and rolls, in such a way as to show through even the finish coat.

Care should be taken to see that each coat invariably is absolutely dry and hard before the addition of another coat is attempted. Otherwise the later coat will fall off, in greater or less part, and it will be quite impossible ever to obtain a good surface finish; while, if it should

happen that the first coat is only partially dry when the second is applied, it will be seriously injured by the pressure brought upon it when floating. Its clinch to the lath is thus often partially or wholly broken, sometimes the plaster falling entirely off, leaving the laths exposed.

The finish second coat in two-coat work is the same as the final skim coat in three-coat work.

The Finish Coat. The *finish*, *skim*, or *white coat* should never be applied until the earlier coat or coats are thoroughly dry and hard, as it is liable to crack if put on before—quite aside from the possible danger of injuring the first-coat work by the pressure of troweling before it is entirely dry and set. A simple putty coat should carry more sand than when the finish is hardened by the addition of plaster. If plaster is used, the mortar should always be *gauged* (that is, plaster should be mixed with the putty) *after* it is placed on the mortar-board. The usual process of gauging consists in making a hollow with the trowel in the midst of the pile of lime putty lying upon the mortar-board. This hollow is filled with water, and the plaster sprinkled upon it, the whole then being mixed rapidly with the trowel and put upon the wall immediately, before the plaster has time to set. The proportion of lime and plaster, while variable, averages probably one-fourth to one-fifth plaster.

The finish is skimmed in a very thin coating that is generally less than one-eighth of an inch in thickness. It is immediately troweled several times, dampened with a wet brush, and thoroughly troweled to smooth up the surface and prevent it from chipping or cracking. The water prevents the steel trowel staining the surface, but the plaster should not be too wet, as it will then blister or peel. The whole surface of the finish coat, whether of putty or hard finish, should finally be brushed over once or twice with a wet brush; while, if a polished (or buffed) surface is required, it may be gained by brushing—without dipping the brush into the water—until a glossy surface is obtained.

Especial care should be taken, in the final coat, to finish all joints smoothly and evenly so that the point of jointure will not be apparent. The ceilings are completed first; then the upper part of the wall; and lastly the bottom portions which can be reached from the floor and thus more carefully finished up to the joint.

The plasterer generally scaffolds the room with boards at a sufficient height to enable him easily to reach the ceiling overhead without raising his arms too high to work each of the coats evenly. The plaster is applied on the upper part of the walls from the same scaffolding, and the remainder of the work is completed from the floor. If too much time elapses in joining the coats at this point, the joint is likely to show—which is, of course, not serious unless the walls are to be left untreated. Occasionally two men working along together, one on the scaffolding and one on the floor, finish the walls at the same time.

If the old-fashioned wooden angle-beads are used, the plaster should be neatly cut out from each side, forming a small V-sunk angle that prevents the thin edge running up against the corner-bead from breaking off. As a matter of fact, the use of a metal corner-bead makes a far truer, sharper, and straighter angle, and one that does not afterward tear or break the papering when it is put upon the wall. Angles in the plaster are generally finished with a wooden paddle.

As the hair is used principally to insure a clinch back of the lath, if plaster is applied on a stone or brick wall, a scratch coat is seldom necessary; and the coat of brown mortar is very often used without hair and of about the composition of brick mason's mortar. If a scratch coat is used under these conditions, it is generally mixed with more sand and less hair than when put upon laths.

For a finish where plaster mouldings are to be used, or when for any purpose an unusually straight, level, and plumb surface of plaster is required, three-coat work, put on in the old-fashioned manner, should be demanded. This is necessary in order to get a surface sufficiently level and true to run plaster mouldings evenly, and to avoid the inequalities that are almost certain to occur in all two-coat plastering.

The second and third coats allow opportunities to obtain a straight and level plaster surface. Individual spots are brought up to an even surface, the plaster then being added and carefully worked between and amongst them, bringing it all to the same face by means of the straight edge. Occasionally it happens that the rough coat is so uneven that some filling in is absolutely necessary to make the wall sufficiently even to receive the last coat. In that case, a mixture of half plaster and half putty may be used in leveling up the rough work.

If no finish coat is to be put on, the surface should be troweled smoothly as the mortar is applied, care being taken to leave no marks, hollows, or uneven places; but if the wall is to be finished or frescoed, it should be left with a floated surface.

Patent Plasters. Patent plasters, such as adamant, etc., are not often employed for private dwellings, being chiefly suitable for met-cantile purposes. The patent plaster has certain advantages that are self-evident—such as quick drying and hardening. Its surface hardens more quickly and resists abrasure longer than the ordinary lime plastering. However, a break once occurring, the extreme stiffness of the mixture makes it liable to extend further and to be of a more serious nature than if the softer, more flexible lime plaster covering had been injured in the same manner.

The extra stiffness of most patent plasters is caused by the cement that generally forms an important part of their composition. These plasters are sold ready for use, requiring merely the addition of a sufficient amount of water. They are therefore especially adapted for use by the inexperienced, and are valuable for executing small pieces of work, as they do not present the liabilities to failure, or loss of time and delay, occasioned by mixing up batches of lime mortar.

Back Plastering. Occasionally a wood-framed house is *back-plastered* for warmth. This process consists in nailing a strip of seven-eighths inch furring against the inside of the boarding on each side of the studs. The space between the studding is then lathed (of necessity a slow and bothersome job) and plastered one rough coat of hair mortar, which should be allowed to dry before any lathing is placed over it on the inside face of the studding. As a matter of practice, the efficiency of back plaster is much injured by the fact that the studding, in seasoning after the plaster is set, is likely to shrink away from the plaster, leaving a narrow perpendicular crack on each side of the stud, which permits of the passage of cold air.

Plaster Cracks. Cracks in plaster occur from several causes. If the distance between the ends of the laths, where they join on the studding or furring, is too great, the larger amount of plaster in that place, when drying out, may cause a short crack. Any such spaces should, however, be filled by the lather before plastering is begun. Sometimes, too, especially in the first coats, cracks are caused by the shrinkage or expansion of the wooden laths after the mortar has

wholly or partially set. The result is a series of narrow cracks parallel to each other and the width of the laths apart. *Lath cracks* are ordinarily filled in and covered up by later coats, and so do not often appear in the finished plastering. They may, too, be worked out when floating up the coat before it finally sets. If wide or deep, however, they should be cut out to a width of an inch or so, and filled in with new mortar before adding the last coat.

Cracks of a like appearance are sometimes caused by the rough mortar being too rich, or by draughts of air from open doors or windows drying out portions of the plastering too quickly. The too rapid drying of plaster with stoves or salamanders, often produces a like result from similar causes. An experienced plasterer should be able to determine the responsible cause and take measures accordingly, using more sand if the mortar is too rich, screening openings to prevent draughts, and using less fire in his drying stoves. In green work, damage already done may be repaired by refloating again before the work becomes too dry, softening the mortar with water if necessary.

Cracks sometimes occur in the angles at the ceiling or corners of the room. When in this location, they may be caused by the shrinkage or settlement of the partition or floor. In the perpendicular angles, especially, they may extend only to the depth of the finishing coats. In that case, the causes are likely to be either too thick plaster, insufficient troweling, or an insufficient amount of plaster in the gauged coat—causes which are easily remedied in the remainder of the work.

Cracks running diagonally across a partition, or radiating from the corners of doors and window openings, are caused by the unequal settlement or shrinkage of the building. They frequently occur at a perpendicular angle where a wood partition is brought up against a brick wall, or at the ceiling line where a wooden floor comes up against a brick supporting wall.

Cracks occur in the final finish when the putty is not gauged enough or not troweled or brushed enough, when it is put on too thick, and when too little sand has been used. These cracks are called *chipped cracks*. Plaster, when apparently perfect and without cracks, will sometimes crumble, either from too rapid drying or from the use of too much sand. Either too much or too little sand materially injures the strength of mortar.

If unclean sand, dirt, or clay has become mixed with the mortar, it not only weakens the lime but prevents its adhesion to the sand particles, so that no real set of the mortar ever occurs. Of course, at all times, poor materials—sand, lime, or hair—may be responsible for defects in plastering. Plaster occasionally falls off even when apparently hard and good, if the laths are too near together, if there is insufficient hair, if the mortar is too rich or too sandy, or if it had not been pressed against the laths with sufficient force when being applied; or it may become loosened by the springing of the laths under the pressure of floating it too hard. On brickwork the mortar requires considerable more sand than for application on laths.

Lime must have time to set before it dries out. Therefore, to last well, it should dry slowly. A stiffer working mortar makes better and harder plaster than thin or wet material, provided, of course, it is thin enough to clinch well to the lath in first-coat work, or to adhere to brick and dry scratched surfaces, and to spread evenly, in second-coat work. Stiffer mortar can safely be applied upon wet mortar than on dry; and wide-spaced lathing will take stiffer mortar than close-laid laths. When two coats of mortar have been put on, and the last coat falls from the first, it is generally because the first coat was not wholly dry when the second was applied. The coats must either be entirely dry or quite green to be successfully combined.

If possible, it is better to have the workman use makes of materials, especially lime, having those properties with which he is acquainted. Attention has already been called to the fact that different makes of lime vary considerably in their chemical composition. It is not even certain that lime of the same make will always run even in production, year after year. Of course, lime that has been slaked by exposure to air or water while in the barrel, and before it is used, is worthless. As this occasionally happens, it is well to be watchful and see that such bad material is never added to the plaster bed.

As a final warning, be certain that the last coat of plaster has dried out hard and strong before any wood finish is installed, as otherwise the wood will absorb the moisture from the plaster, causing it to swell and therefore opening cracks that are never likely afterward to be altogether closed. All wood finish should also be kept out of the house while plastering is going on, as it will absorb moisture from the air around it. The reason that sash are not ordinarily set until after

the plastering is finished, is because they absorb so much of the moisture as to cause the sash to swell in place. It is generally considered preferable to fill the window openings or doors with screens of cotton cloth, as this prevents direct draughts and still allows of a circulation of air that dries plastering much more rapidly than artificial heat, or than it would dry if these openings were closed by solid doors and glazed sash. In very bad weather the screen of cotton may be slightly strengthened, if necessary, by the application of a coat of white-wash on the inner side. Contrary to what might be supposed, the cloth window-screen is almost as good a protection against external cold and frost as is the glazed window, although the current of air passing through the cloth meshes of these screens into and out of the house, causes a slight loss of heat, adding somewhat to the expense for fuel required to dry out a plastered building. In good drying weather, these screens should be taken out and left out during the day, but should be replaced at night or in damp weather, when the plaster otherwise is likely to reabsorb moisture from the air and so delay the time of its final drying out.

If avoidable, the artificial drying of plaster by salamanders should not be employed; natural drying by sun and air is, under all circumstances, preferable. The salamander not only dries the room in which it is placed, too quickly—especially the ceiling above—but fills the air and the plaster itself with gas fumes, and, by steaming, is frequently the cause of the rotting of plaster or hair, thus reducing its vitality and life. Heating a house to dry out the plaster by means of the regularly installed heating plant, is preferable to the use of salamanders, the chief objection in this case being occasioned by the unduly rapid drying-out of wall plaster back of or above registers and radiators. The situation is helped if the radiator is set out from the wall and some screen is placed between it and the plaster. A screen may also be employed against the wall over a hot-air register; but there is no means of protecting the plaster on either side of a partition through which a hot-air or steam pipe passes. Such plaster is bound to be severely strained by being dried too quickly.

If plaster is frozen when wet, it is likely to loosen up and injure the whole mass so that it may eventually fall off. The effects of freezing are less troublesome if the wall is frozen after it is dried and has once set. If only slightly frosted, and thawed immediately and

floated again, it may often be saved, the effect in that case being not much different from what it would be if the wall had been surface-moistened and refloated.

Plaster Moulding. Plaster mouldings upon ceilings and walls are less frequently employed now than a few years ago, when, especially at the intersection of wall and ceiling, a heavy cornice of plaster was the common method of finish. Nowadays a cornice of wood is more commonly used.

Briefly described, the running of a moulded plaster cornice is as follows: Two parallel strips, or *screeds*, are run on the ceiling and the side wall, with their nearer edges evenly straightened. These edges are then fitted to the mould—a piece of metal cut out to a reversed section of the cornice outline. The mould is run along the strips fastened to the wall for guiding it, the lower edge being cut out and fitted to run upon them.

The plaster necessary to fill up the mouldings of the cornice may be tied back to the wall and ceiling by rows of nails driven so as to stand at about the location of its greatest thickness; while a strip of metal lath, filling in the angle upon projecting furrings, will offer the best possible clinch, and will help to reduce the thickness of the plaster and render its drying and shrinkage more equable and its surface less likely to crack.

When all is ready, enough putty and plaster are gauged in about equal parts to run the cornice down the length of one side of the room. The moulding form is then rested upon the supporting and guiding strip against the wall, and drawn along from right to left, pressed against the mass of mortar which is thrown into the angle just ahead of it by the trowel, the space immediately in front of the moulded strip being kept sufficiently full of plaster mortar to fill out the moulding entirely at all times. When the length is completed, or the gauged material is used up, the mould is moved back and forth along the length of cornice that has just been run, scraping away all the plaster except that included within the outline of the mould.

Where hollows occur, the gauged material scraped off by the mould should at once be thrown on again at these places, so that they may be immediately filled and brought up to the right section outline by again running the mould over these portions. The gauged putty will set in a few moments, and each side of the room or section of the

moulding must be run and completed or filled out very rapidly. The corners at the angles of the room may be filled in by hand, or a section of the mould may be separately run upon the floor, sawn in a mitre box, mitred and fitted in place upon the wall, the joint between the cast and run moulding being then carefully patched and evened off.

The extra amount of plaster included in the thickness of extreme projecting mouldings is the cause of occasional surface cracking; while other cracks are occasioned by the settlement, shrinkage, and movement of the house frame. For these and other reasons, it is now generally considered that a wooden cornice, despite its defects of shrinkage, is better suited than plaster to this purpose.

Finally, the moulding may be sprinkled with the brush and the mould may be run over it several times more, ending by finishing with a brush so as to give the moulding a gloss just as on the wall plastering. The same process is repeated for different kinds of plaster moulding, merely varying the method to provide for the different conditions set by circumstances, a circular moulding around the lighting outlet in the middle of the room, for instance, being swung from a peg driven into the center of the gas pipe or outlet box. Other kinds of plaster mouldings are run by unimportant variations of the processes described.

Cast ornaments are made separately in moulds, into which the plaster is poured. Most of these separate moulds are made of plaster hardened with glue or shellac, or surfaced with beeswax, and are generally oiled before being used. Plaster ornaments are fastened in place with fresh plaster or glue; occasionally a few screws are used, in which case the heads should be countersunk and covered in with plaster so as not to show.

EXTERIOR PLASTERING

Although exterior plaster surfacing for dwellings has been in use in Europe for many years, it has but recently met with favor in this country. In Italy, plaster, or stucco, applied in large, unbroken expanses upon a stone or brick building, has long been a favorite method of construction. Frequently, too, this plaster surface is stained or colored and worked up into different designs. In England, France, and Germany, plaster has been more frequently used in con-

nection with a half-timbered frame, although these countries also contain instances of its use in large, unbroken, simple surfaces.

In modern American work, it is not often that a brick wall is covered with plaster, as the æsthetic possibilities in the use of rough hard-burnt brickwork have now long been recognized; and when this—the cheapest brick-building material—is employed upon a dwelling, it is itself utilized for the exterior surface and to obtain the exterior effect of the structure.

Plaster has been used in this country in imitation timbered houses for some years; but recently its employment in large, simple surfaces, unbroken by the cross-barring strips of dark wood, has become popular—a treatment much more appropriate to this country. We also possess some examples of brick and stone houses, two hundred years old or thereabouts, that were covered and surfaced with white plastering; but in the most recent of American plastered dwellings, this effect has been simulated by applying the plaster to a wooden frame lathed with a fine-meshed wire cloth.

In any plastered building, the cornices should be projected sufficiently far to protect the walls and all exposed upper surfaces of the plastering. The farther this projection, the more certain the safety of the plaster, especially in the northern sections of the country.

The essentials for successfully-wearing exterior plaster applied in modern fashion, are: A well-seasoned, shrunk, and settled frame; a solid, immovable foundation; and a carefully applied and thoroughly worked job of plastering. The framework should be somewhat better constructed and more carefully arranged to prevent movement or settlement than on an all-wooden building. Other than this, the dwelling to be plastered outside does not differ, in any part, from the ordinary house, until the structure has been framed and boarded in. For plastering, the boarding is then covered with a slightly better and more waterproof grade of paper than if shingling or clapboarding were intended. Outside of this papering, the house is furred with strips of furring, seven-eighths of an inch thick by one and one-eighth to one and one-quarter inches wide (for metal lathing they are to be placed nine inches apart, for wood laths twelve inches, on centers), and the lathing is applied upon these strips.

METAL LATH

The best lath for exterior plastering is probably the No. 19 Clinton wire cloth. The wire is sufficiently large to be durable, and the mesh sufficiently open to allow the mortar to press through and completely fill and close in over the back of the wire, thus protecting it from exposure to the elements or damage from water and rust, even if the plaster surface should leak sufficiently to admit water behind this covering. Expanded metal is also used for this purpose, but it is not generally considered so good a material, from the fact that it is impossible to cover entirely and protect the back of this lath with plastering, and therefore there is no means of certainly protecting it from the possibility of rusting.

Occasionally, on a small, low house of not over a story and a-half of wall height, the boarding may be omitted altogether. The metal lath is then placed directly upon the furred studs, and plastered both outside and in to insure its absolute protection from damage by water. However, the shrinking of the studs opens a small crevice along each side—which has already been mentioned as occurring in back plastering—and it is thus possible that water may enter from the back and do considerable damage, even through the narrow space that this shrinkage provides. The omission of the outer boarding also somewhat injures the stiffness of the house, as a frame constructed in this way is not so well braced as when the boarding is applied. Neither are the dwellers in the house so completely protected from the exterior weather, as the second air-space obtained between the papering and the exterior plastering is lost. This extra air-space is of assistance in keeping the house more equably warm in winter and cool in summer.

In the use of metal lath, it is always to be remembered that the *absolute* essential is to protect the lath from the action of water and rust. This once done—in whatever fashion—a permanent and lasting plaster surface is ensured. Sometimes the metal lath is wired and fastened to perpendicular iron furrings of tee-irons or angles, held to the wood frame with staples or some similar fastening, allowing any possible movement of the frame to occur without affecting or straining the plaster surface, which is by this means disassociated from, while directly supported by, the house frame. Cracks around the windows and the angles of the buildings are thus prevented; but

it is a more expensive form of construction, and is not now employed except in the larger and more expensive residences.

From the use of wire lath, there are occasionally obtained small surface cracks, especially if the lath joint happens to come at a place where some strain is afterward placed upon it, and particularly where it is weakened from the movement of adjacent portions of the building. For instance, if a perpendicular lath lap is made on the line of the edge of the window finish, a crack on the line of this joint is almost certain to appear in the plaster, extending both above and below the wood-surrounded opening. Care should be taken to cut the strips of lathing so that the joint will come at least nine or ten inches on either side of the edge of the window or door finish. All furrings should also be kept away and back from all angles, internal or external, upon the walls, so that a certain clinch may be effected by the plastering at these important points.

WOOD LATH

Wood lath is occasionally used, and, in certain sections of the country, apparently with good results. It may be employed in two ways— one, in the ordinary manner, only spacing the laths somewhat further apart than would be advisable on the interior of the dwelling. The other method consists in laying the laths diagonally over the building in such a manner as to form a criss-cross lattice-work. In this case the distance between the laths is from three-quarters to seven-eighths of an inch, so as to allow the plaster to enter easily and form a solid clinch behind these lattice openings. The purpose of the diagonal criss-cross lattice is to provide more or less flexibility for the wall covering, so as to take up, without injuring or cracking the plastering, a certain amount of the movement that may always be expected in a wooden-framed dwelling. This method of employing lath, by the way, is in most localities almost as expensive as the use of wire or metal lath, which is probably a safer and surer material to employ. As large and as good a quality of heavy wood lath as can be secured, should be provided for exterior work. Lath cracks are also then to be expected, from the same reasons that apply to interior work; while the mortar should be somewhat softer and slower drying when used upon this material than when employed upon a metal surface.

If possible, it is advisable so to arrange the work upon the house that, after the completion of the frame, some time will still elapse

before the plaster is applied. If the frame can be boarded in, and the interior of the house plastered and finished under artificial heat during the winter, and the exterior plaster added in the spring, probably the best results are to be expected. Opportunity is then provided for the frame to shrink, settle, and contract. Most of the weight to be placed inside of the building is then also installed before the exterior surface is applied, so that much less strain and movement may be expected afterward to affect it than would be probable under the opposite conditions.

PUTTING ON THE PLASTER

Exterior plaster requires three-coat work. The first or scratch coat is indispensable when metal or wire lath is used, but almost equally important over wood lath. This first coat should be scratched or roughened while drying, and must be thoroughly dry before the second coat is applied. A greater time ought to elapse between the applications of exterior than of interior plaster coats, inasmuch as it then becomes possible to cut out many of the larger and more important cracks than have had time to appear, and to patch them before the second coat is put upon the house. The second or brown coat is then the less likely to crack; and, if a further extra time is allowed the plastering to dry, it can also be patched at the last moment before the final slap-dash or finishing coat is put upon the walls. This slower progress aids in giving a more permanent job and one that is at the same time less likely to give annoyance from surface cracks afterward making their appearance in the finish plastering.

The question of proportion in mixing the plaster is quite as variable here as in the case of interior plastering, and it is equally impossible to give absolutely definite directions. Different plasterers, each being guided by the experience obtained from working in different sections of the country, prefer their individually different ways of proportioning or mixing their materials. In the first coat, cement is added to the lime mortar in proportions varying between ten and forty per cent of the mixture. Some plasterers prefer that the first coat should be less stiffened with cement than the second. With others the reverse is true; while, contrary to the general supposition, the exterior coat appears—in the majority of cases—to contain only that amount of cement necessary to provide the tone or color that is desired

for the exterior treatment. Conditions also greatly affect these proportions. When the plaster is added last on a well-seasoned and shrunk frame, for instance, it is worked stiffer than when the building is newer and still far from finished.

The final coat for exterior plaster is generally applied as a *slap-dash* finish, the surface texture being given by the throwing of handfuls of variously sized pebbles or gravel upon the fresh outer coat, thus pitting or marking up its surface. The smaller the size of the particles employed for this purpose, the more likely they are to stick and remain in the fresh putty, slightly tinting the surface with the color—if any—of the gravel employed.

The coloring of exterior plastering is done in much the same way as when it is used inside the dwelling. As a rule, it may be said that not sufficient consideration is bestowed in this country upon the possibilities provided by the use of color for exterior plaster work.

It is agreed that the utmost care to prevent absolutely any leakage is necessary on the part of the workman in the carrying out of this class of work; and it is here that the success or failure of exterior plastering most often hinges. Of course, the joints occasioned by the juxtaposition of the wood finish and plaster around window and door openings offer many opportunities for leakage. The plaster should here be carefully flashed; and, if possible, an outer architrave backband should afterward be put on so as to cover and protect this joint. Otherwise, a key should be provided for the plastering, by cutting away or hollowing out a space near the inner edge of the wood façure, into which the plaster may be pressed by the workman, and leakage thus prevented even if the wood, as is quite likely, shrinks slightly away from the plaster after it has been put in place.

The problem of making tight this exterior plaster wall is complicated and rendered more difficult when it is divided into panels by a so-called *half-timber* treatment. In this style of design, a great number of joints between plaster and wood are occasioned where the wide wood boards are almost certain to shrink away from the plastering, and where, too, it is impossible to protect these joints by outer applied battens in any way capable of covering such an opening as may occur. Thorough flashing on all upper exposed surfaces, assisted by protecting overhang of the roof eaves, and broad keys provided for the entrance of

the plaster at all perpendicular and lower horizontal joints, must alone be relied upon.

Under no circumstances, so far as the lasting value of the work is concerned, does the mixture play so important a part as the expending of great care upon the thorough surfacing, working, and finishing of the mortar, pressing it into every crevice provided to receive it, flashing thoroughly every exposed or upper surface provided by the finish, and taking every precaution to work out all pinholes or other defects where water could possibly penetrate the surface. Every care and endeavor is directed to providing a solid, evenly worked, and permanent coating which will, in every possible way, throw off and prevent moisture being admitted into the space back of the plaster coating—that vulnerable portion where its attack is most effectually concealed and most to be dreaded.

The exterior plaster treatment of a cement or concrete wall is a problem that from now on will continue to be of rapidly increasing importance. Here, however, it is but necessary to use the cement as nearly *neat* as possible, adding lime or a make of white cement in case a brighter surface color is desirable. The problem of the æsthetic treatment of concrete construction is one that requires separate and particular consideration. Its solution has, as yet, been hardly attempted. Hollow terra-cotta tile is another material that is being modernly used more and more as a structural base to take an exterior plaster surface finish.

The student desiring to obtain a wider knowledge of the intricate subject of exterior plastering, may be referred to several articles published in the 1907 numbers of *The Architectural Review*, Boston. For a work treating historically and practically of the entire art and craft of plastering—within and without the dwelling—see Mr. William Millar's treatise "Plaster, Plain and Decorative." It would be as well to remember, in consulting the latter volume, that it was issued in 1897, and that the subject is treated from the point of view of an English workman, accustomed to methods and materials somewhat different from those common in American practice.



HOUSE AT CANTON, ILL.

R. C. Spencer, Jr., Architect, Chicago, Ill.

Paving Brick Walls; Stud Frame Above, Plaster on Metal Lath, Paneled by Undressed and Stained Boards; Red Shingle Tile Roof.

PAINTING

Introductory. The first thing a man wishes to know when he contemplates painting a house, is the *cost*. This will obviously depend on the cost of labor, of materials, and the kind of materials chosen. The outside of a house is painted, either in whole or in part; the interior may be painted or varnished. Some houses have their walls partly covered with shingles; these shingles are sometimes painted, and sometimes—in fact, often—left unpainted; but what is called the *trim*—that is, the boarding about the eaves, windows, doors, the base-board, and corner-pieces—is painted. Shingles, either wall or roof, are often stained with a creosote stain consisting of a coloring matter dissolved or suspended in a liquid called *creosote*, which is applied for the purpose of preserving them; and though instances can be cited in which wall-shingles that were never stained are still doing good service although believed to be now two hundred and fifty years old, yet the use of creosote will undoubtedly prolong the life of modern, sawn shingles, as it is noxious to insect life and a powerful deterrent of natural decay. The color of unpainted new shingles is generally disliked; but after four or five years wall-shingles take on a beautiful, soft color. The question of staining shingles is a matter of taste.

Most houses are exteriorly painted with paint based on white lead or zinc. Some idea of the cost may perhaps be gained from the following considerations:

White lead is sold either ground with a little oil to a thick paste, or—less commonly—in the dry state.

A mixture of 100 pounds of dry white lead with 5 gallons of linseed oil, makes $6\frac{1}{2}$ gallons of paint, weighing 21.3 lbs. per gal.

Approximate figures are: 15 lbs. paste lead and 6.3 lbs. oil equals 1 gal. (1 gal. oil equals 7.7 lbs.); 14 lbs. dry lead and $7\frac{1}{4}$ lbs. oil equals 1 gal.

A mixture of 100 pounds of white zinc and $8\frac{1}{2}$ gal. oil, makes $10\frac{1}{2}$ gal. of paint; 12 lbs. zinc and 1 gal. oil make 1.3 gal., or 9.5 lbs. zinc and 5.7 lbs. oil make 1 gal. white zinc paint weighing 15.2 lbs. Dark-colored paints made from iron oxides, ochers, and the like, weigh 12 to 14 pounds per gallon; but exact figures cannot be given, as the raw materials differ greatly.

Here should be noted the difference between the priming coat and the succeeding ones. A *priming coat* is the first coat applied to the

clean wooden surface; it differs from the other coats in containing more oil, because the wood will soak up the oil and leave the coloring matter of the paint on the outside.

To make the paint for the priming coat, take a gallon of the paint already described and mix with it a gallon of raw linseed oil. Paint thus made is, of course, lower in price; it is also much thinner; but such is the absorbent power of the wood, that the priming paint does not cover as much surface as the succeeding coats per gallon. A gallon of this thin priming coat covers 300 to 400 sq. ft., while a gallon of second or third-coat paint, well brushed out, will cover about twice this surface; this is because the surface for all but the first coat is hard and non-absorbent. Priming coats are used for both outside and inside work, as will be described later.

The dark-colored paints are usually cheaper than those made from lead and zinc, and if made of good materials are not inferior in durability; the extraordinary claims made by the zinc and lead manufacturers are to be received with much doubt. Some of the dark-colored paints are the most durable that can be applied on wood. The chief cost of painting is, however, that of labor, which varies according to locality and other conditions, seldom being less than twice that of materials.

For light-colored paints, it is better to use raw linseed oil to which pale japan dryer may be added, as described later; for dark colors, either this or boiled oil, boiled oil being darker in color. The cost is practically the same; also the durability.

On inside work may be used either oil or enamel paint, as described later, the former being the cheaper, the latter the handsomer and slightly more durable; or the wood may be finished in its natural color, by varnishing it either with an oleo-resinous varnish or with shellac varnish. The oleo-resinous varnishes darken the wood very appreciably, while white shellac varnish keeps it more nearly in its natural color; although the latter does not prevent the natural darkening action of light, it may retard it. Shellac varnish is the more expensive finish of the two, if well applied. What is sometimes called *oil finish* generally consists in the application of a cheap varnish called *hard oil*, which is usually made of common rosin, linseed oil, and benzine. Its only merit is that it is cheap.

It would indeed be possible to apply neither paint nor varnish, but merely to saturate the wood with oil, and this would be truly an oil finish; it would, however, make the wood dark and dingy, and would readily retain dirt, and is a practice seldom followed except sometimes on floors—especially kitchen floors—and sink shelves. These are at frequent intervals oiled with a mixture of equal parts boiled oil and turpentine.

It is the purpose of this Instruction Paper to describe only good and approved methods. It will readily be understood, and will certainly be observed in practice, that these methods may be abbreviated by the omission of some details that are here specified as desirable. For instance, it is difficult to get interior finish sandpapered or rubbed between coats, even if so contracted; but this is the right practice. Two coats of varnish often have to serve in the place of four. No one, however, needs to be told these things. The methods herein described are not luxurious or extravagant; they are, on fairly good houses, truly economical; and we are not considering temporary structures.

It is not uncommon to find part of a house, as the living rooms, finished in varnish, and the kitchen and pantry painted with oil paints, which are lighter in color and more easily renewed. The sleeping rooms, on the other hand, are often finished in enamel paints, because color effects are desired to harmonize with the furnishings; and bathrooms are almost always done in enamel for sanitary considerations. The taste and inclination of the owner are to be consulted in regard to all these matters.

PAINTERS' SUPPLIES

Pigments and Vehicles. Paint is a mixture of a finely-divided solid substance with a liquid which, when spread on a solid surface with a brush or otherwise, will adhere and in a short time form—by evaporation, or more commonly by oxidation—a somewhat hard and tough film. The finely divided solid is called the *pigment*; the liquid part, the *vehicle*. The most common vehicle is *linseed oil*. This is an oil obtained by pressure (or extraction by solvents) from flaxseed. When spread out in a film and exposed to the air, linseed oil is converted into a tough, leathery, elastic substance called *linoxin*, insoluble in water and all common solvents. This change is brought about by

absorption and chemical union of the oxygen of the air, whereby the weight of the oil is increased about one-fifth or one-sixth. It is therefore a mistake to suppose that oil paint gets dry as whitewash does, by the evaporation of the liquid. Instead of that, it gets heavier. There are some other vegetable oils which have this property in some degree, but none which are used for paints to any considerable extent; some are used a little for artists' colors.

Linseed oil should stand at least a month or two before using. It should then be perfectly free from sediment or cloudiness; if it is not so, this is a sign that the oil has not been properly aged, and such oil is not fit for making paints. In this natural state, it is called *raw oil*; and the price of linseed oil as commonly quoted refers to raw oil. *Boiled oil* is this raw oil which has been heated, usually to 450° or 500° F., with the addition of a small amount of oxide of lead or oxide of manganese, or a mixture of the two (occasionally some other lead or manganese compounds are used). Boiled oil is darker (brownier) in color than raw oil, but differs from it chiefly in that it dries five to ten times as rapidly. A thin film of raw oil on a glass or metal surface will dry at ordinary temperatures in five or six days, so as to feel no longer greasy; but boiled oil will do the same in a day or half a day. Oil dries best in warm, dry weather and out of doors.

The pigment is mixed with the oil by stirring the two together. This is usually done by power, in a vessel called a *paint mixer*. The mixture should then be run through a *paint mill*; some paint mills are of steel, but the best have a pair of mill-stones, between which the paint is ground and most thoroughly mixed. Paints mixed in this manner are much better than those which are mixed only by stirring.

Besides oil and pigment, paint sometimes contains a volatile *thinner*, the most important thinners being *turpentine* and *benzine*. Turpentine is a well-known essential oil, volatile, boiling at about 320° F., but evaporating at ordinary temperatures when exposed to the air. Benzine is a mineral oil, lighter than kerosene and heavier than gasoline; the kind used in paint and varnish is called "62-degree benzine," its specific gravity being 62° on the Baumé scale for liquids lighter than water. Linseed oil weighs 7.7 lbs. per gallon; turpentine, 7.2 lbs.; and 62° benzine, 6.1 lbs. But linseed oil is sold by the oil makers and dealers on the basis of 7.5 lbs. per gallon.

A dryer, in some form, is an essential ingredient of oil paint. A *dryer* is a compound of lead or manganese (generally both), soluble in oil, and is usually sold, under the name of *paint dryer* or *paint japan*, as a solution of such material in a mixture of oil, turpentine, and benzine. It is usually of such strength that an addition of from 5 to 10 per cent of it to a raw-oil paint will make it dry in from six to twelve hours sufficiently to be carefully handled. Paints are not dry enough to use, until they have stood four times as long as this; and they continue to harden for months. The strongest drying japans are dark in color; but such are more injurious to the durability of the paint than those which are paler, especially if the latter do not contain rosin. The buyer should always ask for a guarantee that the dryer is free from rosin, if great durability in the paint is needed. Not more than 10 per cent of any dryer or japan should ever be used in any paint. Slowly drying paints are more durable than quick ones.

In house painting, the white pigments are the most important, because they are the base of all light-colored paints. The most important white pigment is *white lead*. This is sold either as a dry powder, or (more commonly) as paste white lead, which is made of 90 lbs. dry white lead and 10 lbs. linseed oil. This can be thinned with boiled oil to make a white paint. White lead is a very heavy pigment; and with a given quantity of oil, more of it can be mixed than of any other pigment, except red lead. It has great opacity, or covering power. It is discolored by gases containing sulphur, becoming brown or black; and unless exposed to fairly strong light, it becomes yellowish even in pure air. It is better if it has been mixed with the oil for some time—a year or more.

White zinc is a somewhat purer white than white lead; not so opaque. Three coats of lead are reckoned equal to five coats of zinc. It becomes harder than lead, but is somewhat liable to peel off; while lead, after exposure to the air for a long time, becomes dry and powdery on its surface, and *chalks*.

A mixture of two parts of lead and one of zinc is much liked. *Zinc-lead*, however, is the name of an entirely different pigment, made by furnacing ores containing about equal parts of lead and zinc, in which the lead is present as a sulphate. This pigment is free from the liability to turn brown if exposed to sulphur gases; it is said to be not quite so pure a white as the preceding. It is a comparatively new

pigment, but is coming rapidly into use, being somewhat cheaper than the others. *Lithopone* is another white pigment of considerable merit.

Adulterants. All these pigments may be *adulterated* with barytes, or with *terra alba* (sulphate of lime), sometimes with whiting (carbonate of lime). These adulterants are powdered minerals. Barytes is a good pigment, so far as protective action goes; and *terra alba* is thought by some good authorities to be unobjectionable; but whiting is injurious. All of them are transparent in oil, and lessen the opacity or whitening power of the paint.

From these white paints, *colored paints* are made by adding *tinging colors*, of which the yellow is chiefly *chrome yellow*, or *chromate of lead*; the blue may be either *ultramarine* or *prussian blue*; and the green is *chrome green*, a mixture of chrome yellow and prussian blue. The reds are (in house paints) made from *coal-tar colors*, and most of them are now fairly fast to light. Some dull yellow colors are made from *ochers*, which are clays tinted with iron oxides, roasted and ground. These are permanent colors.

The dark-colored paints may not contain lead or zinc at all. The deep yellows, greens, and blues are made from the colors already named as tinting colors, none of which are entirely fast to light; the dark reds and browns are chiefly *iron oxides*, which are a valuable class of paints, very permanent on wood. The blacks are either *lamp-black* or *drop-black* (bone-black) and other carbon colors; and these are often added in small quantity to secure some desired tone or shade of color.

The zinc and lead pigments have some action on oil, and in their case it is considered the best practice to apply thin coats; but the dark pigments do not act on oil, and, of these, thick coats are best for durability.

Paint and Varnish Brushes. A brush that has only a low price to recommend it will prove a poor investment. If properly cared for, brushes last a long time, and it pays to have good ones. The first sign of a good brush is uniform quality from outside to center. Inferior brushes have inferior bristles in the middle, and some poor brushes are actually hollow. For ordinary oil painting, the bristles on a large new brush should be five or six inches long, uniformly flexible, and as stiff as can be found; they will be flexible enough anyway, but all should be alike.

Paint brushes are *round*, *flat*, or *oval*. A favorite brush for ordinary outside work is what is called a *pound brush*, a large, round brush with stiff bristles six inches long. Such a brush should be *bridled* when it is new—a “bridle” being a piece of cord wound around the bristles to shorten their effective length; as the bristles become worn off, the bridle may be removed. A 2½-inch oval brush (2½ inches wide) is a highly satisfactory tool to use in general painting, and is the brush recommended by the paint committee of the American Society for Testing Materials. It is worth noting that this committee, made up equally of expert paint manufacturers and experts employed by the large consumers, unanimously agreed that no larger brush than this should be used in making paint tests.

The use of brushes five inches wide is common for outside work; but while such brushes may be had of the best quality, they are heavy and laborious to use, and the workman who uses such a brush will not brush the paint sufficiently to get the best result. If a flat brush is used, it should not exceed 3½ inches in width; and three inches is better. A good 2½-inch oval varnish brush is a most excellent brush for all large work in either paint or varnish. The painter should also have a good 1½-inch oval brush for smaller work, and a number of round or oval brushes, called *sash tools*, of different smaller sizes, for more delicate work, such as sash and frame painting. Stiff-bristle brushes, which have been worn off short, are suitable for such work as rubbing-in filling. For varnishing large surfaces, flat bristle brushes 2½ inches wide are good; also similar ones 2 inches, 1½ inches, and 1 inch wide are useful. All flat brushes should have chiseled edges. For flowing varnish, it is necessary to have thick, flat, camel’s-hair brushes, running up to 3½ inches in width, although most house varnishing may be done with brushes not over 2½ inches wide.

Besides paint brushes, the workman will need some ordinary *scrubbing brushes* and one or two painter’s *dusting brushes*, to have the surface properly cleaned.

Steel-wire brushes, with stiff steel wire instead of bristles, shaped like scrubbing brushes, are used for cleaning off old paint and for cleaning structural metal work. These are of various sizes; and the steel wires are of different lengths and sizes, hence differing in stiffness. They may be had at hardware stores.

Care of Brushes Hair and bristle brushes must be kept clean

and soft; this can be done by care and faithfulness. They should not be allowed to become dry with paint or varnish in them. To prevent this, wash them out in oil or turpentine as soon as you are through using them; or they may be left in the paint or varnish for a few days. They may be kept over night by wrapping them very closely in paper if they have been used in a slow-drying material; in this way they may be carried from one place to another. Brushes should not be left to dry with even clean oil or turpentine in them; if they are to be put away, they should be well washed first with soap and water, then with clean water, then hung up until thoroughly dry.

In use, brushes are best kept in what is called a *brush safe*. A deep wooden pail, with nails driven in its sides at different distances from the bottom, and with a close cover, makes a good receptacle for brushes. The brushes have holes in their handles, or loops of cord tied to them, and are hung on these nails; their bristles dip into some turpentine or oil in the bottom of the pail; they are so hung that they do not dip into the liquid above where the bristles project from the binding. If brushes are left standing on the bristles on the bottom of a vessel, they soon become one-sided and distorted in shape. Tin brush-safes may be bought of any large dealer in brushes.

A brush which has dried with paint or varnish in it, may be recovered by soaking it in a non-alkaline varnish-remover. This will in time soften it so that it may be used again, but it is not improved by such treatment. Brushes used in shellac should be washed out with alcohol instead of turpentine or benzine. No brush is good unless it is clean.

Fillers. Fillers are of two kinds—*paste* and *liquid*. Paste fillers are something like a very thick paint, and are composed of some solid powdered substance, usually silica or powdered quartz, mixed with a quick-drying varnish thinned with turpentine or benzine. This is applied to the dry surface of the wood with a stiff, short-bristle brush, or is put on with a clean, white cotton cloth, and well rubbed into the pores of the wood. After half an hour or so, the surface of the wood is wiped off with a wad of excelsior or a clean cloth or a piece of felt. A liquid filler is a quick-drying varnish; and most of the liquid fillers on the market are cheap rosin varnishes loaded with dryers, and should never be used. Paste fillers are the best in almost all cases.

HOUSE PAINTING

Inside Work. All window and door frames, whether they are to be finished with paint or varnish, should receive a good coat of paint made with some cheap pigment, such as iron oxide, and boiled oil, applied to the back of the frame, before they are brought from the shop to the house; this prevents the absorption of moisture and hinders decay. If they are to be painted, they should receive a priming coat in the shop, if possible; if not, it should be applied as soon as practicable. The priming coat is composed of white lead and boiled oil or raw oil, with five to ten per cent of dryer; and should be almost all oil, with very little pigment. Turpentine is not a good thing in a priming coat, because the object is to fill the pores of the wood, and turpentine evaporates. As soon as this is dry to the touch, all holes are to be filled with putty. The best putty for this purpose is white lead putty, made by mixing a little raw oil with dry white lead, or by adding dry lead to paste lead until it is of the right consistency. This kind of putty hardens quickly as compared with common putty, and is the best for this purpose. A steel putty-knife should not be used on interior woodwork, as it is almost certain to scratch it; a hardwood stick, suitably shaped, should be used. All cracks, joints, and nail-holes should be carefully filled. All knots and sappy places should be varnished with shellac varnish; this prevents the pitch and moisture from attacking the paint. The shellac should be applied where it is needed, before the priming coat. The priming coat should be given time to get quite dry; at least a day—two days, if possible; and a week is better yet. Then it is ready for the second coat. This should contain a considerable amount of turpentine. If no turpentine is used, the surface is likely to be glossy, and the next coat of paint will not adhere well; but by replacing part of the oil with turpentine, we get what painters call a *flat coat*—that is, one which is not glossy; if this is made from paste lead or any paste paint, it can be produced by thinning the paste with a mixture of oil and turpentine in equal proportions; some painters prefer one-third oil and two-thirds turpentine. This is for inside work only. This coat should be allowed to dry thoroughly; if it takes ten hours for the paint to be dry enough to handle, then at least four times ten hours *additional* should elapse before the next coat is applied; this is a good general rule; and as much more time as possible should be allowed. If the finish

is to be ordinary oil paint, the next coat may be paint, thinned with about half as much turpentine as before, or with no turpentine at all. In the latter case, when the coat is thoroughly dry, it must be carefully examined, and, if glossy, it should be rubbed with something to take off the gloss; curled hair is often used, or a light rubbing with pumice and water. Then the final coat, which has no turpentine in it, may be applied.

But if the finish is to be with an enamel paint, the second coat, when quite dry, should be very lightly sandpapered with fine sandpaper, and the third coat should be of like composition to the second, treated the same way; then the enamel paint is applied. For a really first-class job, when this is quite dry, it should be rubbed down with curled hair or pumice and water, and another coat of enamel put on. This may be left with the natural gloss if desired; or it may be rubbed with pumice and water to a flat (dull) surface.

Painting Plastered Walls. Old plastered walls may be painted with oil or enamel paints as though they were wood, remembering that the priming coat will have almost all of its oil absorbed by the plaster. New plastered walls do not take paint well, on account of their alkaline character, which gradually disappears with exposure to the atmosphere. It is well to let a wall remain unpainted at least a year. But if it is necessary to paint a freshly plastered wall, the wall is prepared by some painters by washing it with a solution of sugar in vinegar, the sugar uniting with the lime to some extent; or—more commonly—by washing it first with a strong solution of common alum and then with a solution of soap. After this is dry, it is washed with clean water, allowed to dry, and then painted. The alum and soap form an insoluble compound which closes the pores of the plaster to some extent, and prevents the lime from acting on the paint.

Outside Work. Exterior paints are more elastic, as they need to be far more lasting, than those used on interiors, since the effect of exposure to the sun and rain destroys paint more than almost anything else does. Paint on the interior of a house will last almost indefinitely; but on the outside the best paint is not very durable. The surface, if new, should be cleaned by brushing; knots should be shellacked; after which the priming coat should be applied. This may be the same paint which is selected for the finish, only thinned with boiled oil (or raw oil and dryer), using one to one and a-third

gallons of oil to each gallon of paint. The reason why ordinary paint may not be used as a primer, is that the wood absorbs the oil, leaving the pigment as a comparatively non-adhesive powder on the surface, from which the next coat will probably peel off. The next step is to putty up all nailholes and other defects. For the second coat, many experts advise the addition of half a pint of turpentine to the gallon of paint; others make no addition to it. The third coat is applied after the second is thoroughly dry; if a week or a month can elapse between these coats, so much the better.

Repainting. If the old paint has been on a long time, it is liable to be permeated by minute cracks, which admit moisture to the surface of the wood and loosen the paint. If now we paint over this, the new paint, which shrinks in drying, tends to pull off the old paint, and of course the whole peels off in patches. If the old paint is in this state, it must be removed before the new paint is applied. This can be done by *burning off*. For this work a *painter's torch* is required, which is a lamp burning alcohol, gasoline, or kerosene, and is so constructed that a blast of flame can be directed against the surface. This melts or softens the old paint, which is then immediately scraped off with a steel scraper. The paint is not literally burned, but is softened by heat so that it can be scraped off. In some cases it is sufficient to remove as much as possible with a steel brush; this is a brush like a scrubbing brush, with steel wires instead of bristles, and, when vigorously used, will take off the loose paint.

Old paint, however, is not always in this condition. If it adheres well, it may be cleaned with an ordinary scrubbing brush and water, and when it is quite dry, the new paint may be applied. Sometimes the paint seems in good condition, only it has faded and lost its luster; in such cases a coat of boiled oil, or raw oil with dryer, is all that is needed.

It is well to paint the trim—that is, the window-casings, door-casings, corner-pieces, and the like—before painting the body of the house; then the paint can be applied to the flat surfaces more neatly than is otherwise likely to be done. Paint should be applied in thin coats, well brushed on; it is not unusual to see paint come off from re-entrant angles while it is still good on flat surfaces, because it was difficult to brush the paint properly in those places. There is a great difference in durability between a thin paint flowed on with a large,

flat brush, and one of proper consistency well brushed out with a brush of medium size. In all painting on wood, it is desirable to brush it on with the grain of the wood; and by painting only a few boards at once, we may avoid laps by painting the whole length. Rough surfaces hold paint better, and more of it, than smooth. A gallon of paint will cover, one coat (on a painted or well-primed surface), about 600 square feet, not flowed on, but well brushed out in a thin film. The priming coat will not cover more than 300 or 400 square feet to the gallon. In measuring the outside of a house for surface, make no deductions for doors and windows; if the trim is to be painted a different color, from one-sixth to one-third of the paint will be required of that color. Paint should be stirred frequently while using. A coat of dry paint is from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in thickness.

Roof Painting. Roof paints should contain a larger proportion of oil to pigment than other paints, and less dryer (or none at all). Many think that the addition of ten to twenty per cent of fish oil to a paint for roofs is advantageous; fish oil greatly retards drying and prevents the paint from becoming brittle. Tin roofs, if new, should be thoroughly scrubbed with soap and water, or with pieces of harsh cloth, such as burlap, well wet with benzine. They may then be painted.

Paint dries relatively fast on roofs; but as a roof paint is very slow-drying, plenty of time must be allowed between coats. A new roof should receive three coats. Metal gutters and spouts are to be treated the same way. Do not forget that new tin or galvanized iron is difficult to paint; have it very thoroughly scrubbed, even though it looks perfectly clean, and then rub the paint on well with the brush. Metal spouts will usually be painted the same color as the wall of the house.

Sometimes shingle roofs are painted with fireproof paint. This is not really fireproof, but considerably retards the spread of fire, after it has become thoroughly dry; when fresh, it does not even do that; nor does it have much effect after it has been on a year or so. It may be made by adding to a gallon of any good paint about a pound of powdered boracic acid. When strongly heated, this material fuses and forms a sort of glass, which keeps the air from the wood. It is after a time washed out by the rain.

Canvas roofs are prepared in the following manner: The canvas

(10-ounce duck is often used) is first nailed down, care being taken to draw it tight; it will show some wrinkles, but these are not to be allowed to accumulate to form a large wrinkle or fold. Then the canvas is thoroughly wet; it shrinks, and all the little wrinkles disappear. It is a common practice to paint it while it is still wet, this being an exception to all other practice; but some wait until it is dry. The writer has been accustomed to the latter method, and has not found that the canvas shows wrinkles on drying, while the results are all that can be desired. A well-painted canvas roof is very durable and satisfactory.

PAINTING STRUCTURAL METAL

Steel is a more perishable material than wood, and more difficult to paint. Without regular expenditure for maintenance, wooden bridges last longer than steel ones; there are wooden roof beams a thousand years old; and iron roofs are so short-lived that they are used only over furnaces and the like, where wooden ones would take fire. The painting of structural steel is therefore important; and it is also difficult, if we are to judge by results.

In the first place comes the preparation of the surface. When we paint wood, we have the surface clean and dry; and then we soak it with oil, so as to have the paint bound to it in the most intimate manner. Iron and steel, on the other hand, always come to us dirty, and covered with oxide; and as the surface is not porous, the paint does not penetrate it, but has to stick on the outside the best way it can. If we paint over the dirt and scale, and that ever comes off, the paint comes off with it; if the metal is actively rusting, and we paint over the rust, the corrosion is perhaps made slower, but it does not stop.

Air and moisture cause rust; if we can keep them away, the metal will last; but, unfortunately, all paint is very slightly porous, and if exposed to the weather it in time deteriorates. The most essential thing in painting metal is to *get the paint on the metal*, not on an intermediate coating.

There are only two ways to clean steel perfectly. One is by pickling it in dilute acid (usually 10 to 20 per cent sulphuric acid), followed by washing to remove the acid; and the other is by the use of the sand-blast. Neither of these processes is available to the ordinary painter, who must do the next best thing. This is to remove absolutely all dirt and all loose scale and oxide. First clean off the dirt, if any,

with brushes, as it would be cleaned off any other surface. Then, with scrapers and steel-wire brushes, clean off all the scale which will come off. If there is any new rust (not mill scale), it must be well scraped out and cleaned off. This is indispensable. When this is done, immediately paint it, before it begins rusting again.

One of the most popular materials for a first coat is red lead in oil. This must be mixed on the spot, shortly before it is used, because it will harden into a cake in the pail or can if allowed to stand very long. From 30 to 33 pounds of dry red lead is to be mixed with each gallon of oil—not less than 28 in any case. This is immediately painted on the metal; if it is put on in too thick a coat, it will run and be uneven. Some use raw oil, others boiled oil; it does not make much difference which is used. The paint dries rapidly; and as soon as it seems hard, a second coat of the paint can be applied. Red lead is different from all other paints in this, that it will finish hardening just as well away from the air. This is because it does not dry by oxidation, as other paints do, but by the lead combining chemically with the oil, just as water combines with Portland cement. In the opinion of the writer, red lead should have one or two coats of some good paint, other than red lead, over it. But red lead is not the only first coating which may be used. Any good paint may be used—a good graphite paint, or other carbon paint, or some of the varnish-like coatings containing linseed oil and asphaltum which are made for the purpose. It is important, in using any of these, to let plenty of time for drying elapse between coats. Not less than two coats is permissible, and three are desirable.

Projecting angles, edges, and bolt and rivet heads are the places which first show rust through the paint. This is partly because the brush draws the paint thin at such places. To overcome this, it is now becoming common practice to go over the work after the first coat, and paint all edges for about an inch from the edge or angle, and all bolt and rivet heads, with an extra or striping coat; then, when the second coat goes on over the whole, there is the equivalent of two full coats everywhere.

Painting on iron, as on wood, should be done in dry weather, when it is not very cold—at any rate not below 50° F. Full, heavy coats should be used, and well brushed on. Care must be taken to get the paint into all cracks and corners.

VARNISH

A varnish is a liquid made to be applied to a surface in a thin film, which, on exposure to the air, hardens into a protective coating that is usually glossy and almost transparent. There are two principal classes—*spirit* and *oleo-resinous varnishes*.

Spirit varnishes, of which *shellac** is the most important, are made by dissolving a resin (or sometimes some other substance) in a volatile solvent, such as alcohol. They dry by evaporation, the solvent going off and leaving the resin spread out in a thin film, the liquid or vehicle having really served as a mechanical means of spreading the resin over the surface. Shellac is a resin which comes on the market in large, thin flakes. It may be dissolved in denatured (or any other) alcohol in the following manner:

Put the alcohol in an earthenware jar, and weigh out five pounds of gum shellac for each gallon of alcohol. Just before leaving at night, carefully and gently drop the shellac, little by little, into the jar of alcohol, then put on the cover and leave it until morning. Do not on any account stir it. In the morning the flakes of shellac will be soaked and swollen; but if you had stirred them in, the night before, they would have stuck together in lumps. Now, during the day, stir the mass with a wooden stick once every hour or so; do not put any metal in it, especially iron; one iron nail will spoil the color of a whole barrel of shellac. By the next morning—perhaps before—the shellac will be ready for use. It does not make a clear solution, because the gum shellac contains some wax, which does not dissolve, and so the varnish is milky or cloudy; it is, however, ready for use. As the alcohol is volatile, the jar should be kept covered; and after it is made, the varnish should be put in glass bottles or clean tin cans.

There are many grades of shellac gum, the best being known by the letters D C; but there are others nearly as good. The common shellac is brownish yellow, and is called *orange shellac*; this is the natural shellac color. White shellac is made from this by bleaching with chlorine; but it is not of so good quality as the unbleached; it has, of course, the advantage of being much paler in color. White shellac gum will, on long standing, sometimes become insoluble. Shellac

*NOTE.—By some painters, the term "varnish" is never used to include shellac. There is, however, no valid, objective reason for thus limiting the use of the term.

varnish may be thinned with alcohol, and often this is necessary. Shellac is too often adulterated with common rosin, which greatly lessens its value. This is easily detected by a chemical test.

Damar is a white resin which is soluble in spirits of turpentine—five or six pounds of resin to a gallon of turpentine. It is the most nearly colorless varnish we have, but never becomes very hard. It is used to a considerable extent as a vehicle for white lead and zinc, to make a very white enamel paint. It is not durable if exposed to the weather.

More important than spirit varnishes are the oleo-resinous varnishes, which consist of certain resins dissolved in linseed oil, the mixture being thinned with turpentine or benzine. In making these, the resin is put in a copper kettle and heated until it is thoroughly melted; then some hot oil is added to it, and the mixture cooked until the whole is thoroughly combined. The kettle is then taken from the fire, and when partly cool, the turpentine is stirred in. The resin makes the film hard and lustrous, and the oil makes it tough. Thus the larger the proportion of resin, the harder and more brilliant will be the film; the larger the proportion of oil, the tougher, more elastic, and more durable it will be, and the slower it will dry. Most of the color of varnish comes from the resin; the paler this is, the paler will be the varnish. The pale gums are higher in price than the dark ones, but are no better in any respect except color. Dark varnishes may be just as good (except in color) as pale ones—in fact may be better, for the dark resins are often harder and better than the pale ones of the same sort. The hard and quick-drying varnishes are suitable for furniture; the medium, for interior house-varnishes; the slow and elastic, for exposure to the weather.

Varnishing. The wood should be dry. For this reason it is better, if necessary to clean it, to avoid washing as much as possible, using sandpaper instead, which will also make it smooth. Of course the carpenter is supposed to do this, but the painter must not neglect it on that account. When in proper condition, it first receives, if it is an *open-grain* wood, a coat of paste filler. The open-grained woods in most common use are oak, chestnut, and ash. The woods classed as *close-grain* woods are white pine, maple, birch, yellow pine, white-wood, cherry, and sycamore. These latter do not need filling. If filler is used, it should be well rubbed in with a short, stiff brush; and

when it has set, say in fifteen to thirty minutes, it is rubbed off with a handful of excelsior, rubbing across the grain, and rubbing hard, so as to force the filler well into the pores of the wood. Then it should stand 24 to 48 hours.

When purchased, a paste filler is too thick to be used with a brush, and must be thinned with turpentine or benzine; at the same time it may be stained to any desired color with an oil or varnish stain. These stains can be purchased of any desired color. If a close-grained wood is under treatment, the first thing is to apply a stain if it is desired to stain the wood; but it is common practice to finish in the natural color. Stains usually require a good deal of thinning before using; the amount of thinning will determine the depth of color. Water stains are seldom used, as they tend to raise the grain of the wood.

In cleaning off the filler, be careful to clean out corners and mouldings, using for this purpose, properly shaped hardwood sticks; do not use any steel tool.

Where rooms are to be finished in the natural color of the wood, it is nevertheless a common practice to stain the window-sashes; a cherry or light mahogany stain is often used. Fillers are sometimes used on close-grain woods; but this is not advisable, as they tend to prevent the varnish from getting a good hold on the wood.

Next comes the varnishing. Window-sills, jambs, inside blinds, and other surfaces exposed to the direct rays of the sun, are to be treated as exterior woodwork, and are not varnished with the ordinary interior varnish used on the rest of the work. The floors also are left out of account for the present. The rest of the woodwork receives its first coat of varnish; apply it, as much as possible, with the grain of the wood, brushing it out well in a thin coat. The varnish ought to dry dust free (*i.e.*, so that dust will not stick to it) over night; but at least five days should elapse between coats. When dry, it should be rubbed with curled hair or excelsior enough to remove the gloss, so that the next coat of varnish will adhere properly; a better result will be had if it is lightly sandpapered with 00 paper. The second coat is treated like the first. The third is not sandpapered, but rubbed with curled hair; the fourth or finishing coat may be left with the natural gloss, or, if preferred, it may be rubbed with fine pumice and water to a smooth, dull surface. For this purpose the varnish dealers sell felt, about an inch thick, which is well wet in clean water; a little dry pumice powder is

put on it; and the rubbing is done with this. The varnish must be quite hard and dry before this is attempted. Varnishing, if properly done, is slow work; that is, much time must be allowed for each coat to dry thoroughly.

The varnish which is used on interior woodwork should not dry too quickly; it should dry enough over night so that dust will not stick to it, and in twenty-four hours should be hard enough to handle freely; but if a chair, for example, were varnished with it, it would not be entirely safe to sit on it for a week. It should, however, finally become perfectly free from tack, which it will not do if it is a rosin varnish. At present prices (and it is not probable that they will ever be lower) varnishes for interior woodwork are sold, according to color and quality, at prices ranging from \$2.50 to \$4.00 a gallon. It is in the highest degree inadmissible to use a cheap varnish for undercoats; the outer coats will crack if this is done. A good varnish that dries too quickly, such as what is called a *rubbing varnish*, or one intended for furniture, has not the durability needed for this work. It is economy to use a good varnish. The writer has in mind a house which was properly varnished eighteen years ago and has been constantly occupied by a large family, yet the varnish is still in fair condition; if it were lightly sanded and one new coat applied, it would be like new—as good as it is possible for a surface to be. Cheap rosin varnishes never look well, even when new, never keep clean, and deteriorate rapidly.

Shellac. Interiors are sometimes finished with shellac. This varnish is not used on exterior work, but it is a good varnish for interiors. All varnishes containing oil darken the color of wood; but white shellac is comparatively free from this objection; at any rate it does it less than anything else. Orange shellac is a dark varnish, and even white shellac darkens with age to an appreciable degree. Orange shellac is more durable than white, and should be used wherever admissible, rather than white; but it is usually necessary to use white shellac for this service. If shellac is made up as heavy as has been described—five pounds to a gallon of alcohol, and this is the standard—it should be thinned considerably with alcohol before using on interior woodwork. It must be applied in thin coats, and given plenty of time to dry. It is very deceptive about this; it appears to be dry and hard in an hour, and it is hard enough to handle freely; but if we apply coat after coat, even six hours apart, we shall find that the wood is

finally covered with a waxy mess which will be the source of nothing but trouble. The first coat sinks rapidly into the wood; a second coat may be applied six hours later; but after that, allow two days at least between coats. Shellac makes a very thin coat; so it is necessary to apply a large number of coats, at least twice as many as of oleo-resinous varnishes, to get a sufficient thickness of coating. Because of this labor, shellac is an expensive finish; but it is handsome and durable. The treatment of it, as regards rubbing, etc., is the same as has been described for other varnish.

Varnish makers usually advise that shellac should never be used as a priming coat for other varnish; this is probably because they wish to sell more of their own goods, for shellac is really an excellent first coat, except for exterior work, where it should not be used. Of course, wood should be filled before shellacking, the same as for other varnish. Varnish does not, however, wear well over a heavily shellacked surface. Shellac makes a good floor varnish, discoloring the wood very little, and wearing fairly well. After the floor has been well varnished with it, very thin coats, applied rather frequently—say every one to four months, according to use—will keep the floor in fine condition; and after applying one of these thin coats (of thinned shellac), it will be dry enough to use in an hour. This can be applied with a very wide, flat brush, and a man can go over the floor of an ordinary room in a few minutes. Shellac brushes should be washed out with alcohol immediately after using.

Exterior Varnishing. Varnishes dry much more rapidly out of doors than within, so that it is practicable to use more elastic and durable materials. The conditions, in fact, are so severe that the best are not good enough. In the first place, do not use any filler on exterior work; it will probably crumble and come out. Do not use shellac; as an undercoat exposed to the hot sun, it will soften and blister. Use only the best *spar varnish*, such as is made for varnishing the spars of yachts; fill the wood with it; sandpaper lightly between coats, just enough so that each succeeding coat will take hold well; finish with a coat well flowed on; and leave it with its natural gloss, which is more lasting than a rubbed surface. This is the treatment for hand-rails, outside doors, inside blinds, window-sills and jambs, and everything exposed to the direct sun. Hand-rails and outside doors should be refinished every year; varnish will

not last on an outside door more than one-twentieth as long as it will on an inside door. Never use interior varnish for outside work.

ENAMEL PAINTS

Varnishes are all more or less brownish yellow or yellowish brown. Therefore a coat of varnish applied over a paint obscures and changes its color to some extent. To overcome this as much as possible, the varnish, instead of oil, is mixed with the pigment, as a vehicle. In this way the pigment comes to the surface and displays its color. These paints, if made with good varnish, are durable; the method of application has already been described. If necessary to thin them, do it with spar varnish instead of oil; a good interior varnish may be used, but it injures the flowing quality of the paint somewhat.

White lead and zinc are sometimes mixed with damar varnish. This makes the whitest enamel paint, but it never gets very hard, never has much luster, and is not very durable. It is very white, is easily applied, and dries quickly.

A NEW VARNISH FINISH

A method of finishing open-grained interior woodwork, which has been practiced for a few years, consists in first staining the wood with a water-stain—dyeing it, usually—and then, when it is dry, filling the pores of the wood with a paste filler which has been colored by the addition of a pigment. For example, the wood may receive a stain of any dark color, and the wood-filler be mixed with white lead. This shows the open or porous part of the grain in white on a dark background. By using artistic combinations of color in the stain and filler, very beautiful effects can be produced, and this finish has been used in some of the most handsome and costly public and private buildings. Thus, if a room is to be decorated in green, the woodwork can be made to harmonize with the prevailing color. An oil stain must not be used on the wood, as it will not work well with the filler. The colored filler is applied and rubbed off in the same way that any paste filler is used, and then the varnish is applied over it in the usual way.

FLOOR FINISHING

The primary trouble with floors is that people walk on them. If they did not, there would be no trouble at all. Four coats of varnish,

or even paint, having an aggregate thickness of less than one one-hundredth of an inch, will not last indefinitely under the wear of nail-shod heels.

Probably the simplest treatment for floors is painting them. The paint should contain a large proportion of a hard oleo-resinous varnish; an ordinary oil paint is not hard enough. If an oil paint is used, it must be heavily charged with dryer, for a floor paint should dry in twelve hours. Good quick-drying floor paints are in the market.

Floors of choice wood, however, are not usually painted; they may be either varnished or waxed. If they are of oak or other open-grained wood, they must be filled with a paste filler; otherwise the varnish is applied directly to the wood. Floor varnish is quicker in drying, and harder than interior finishing varnish, but should not be so hard as to be brittle; rubbing varnish is too hard. If the floor is to be stained, this is done with an oil stain before varnishing; if it is a floor which has previously been varnished, so that the stain will not penetrate the wood, the stain may be mixed with the varnish, although the effect is not then so good.

Floor wax is not made of beeswax, but of a harder vegetable wax, and is sold by all paint dealers. The floor should receive one coat of shellac; then the floor wax may be rubbed on with a stiff brush, and when it is dry, which will be in a few hours, it may be polished by rubbing with a clean cloth or with a heavy, weighted floor brush made for the purpose. It should receive another coat every week until four or six coats have been applied; after this a little of the floor wax, thinned if necessary with turpentine, should be applied often enough to keep the floor looking well. Alkalies dissolve the wax, and in cleaning the floor only a little soap should be used in the water with which the floor is washed. A wax finish kept polished with a polishing brush, is the handsomest surface than can be obtained for a floor; but it is so slippery that it is somewhat dangerous. It does not discolor the wood. Interior trim (but not hand-rails) is sometimes wax-finished. This finish requires a good deal of care, as it is likely to catch dust; otherwise it is handsome and durable.

Old floors which require cleaning and revarnishing should have the old varnish or paint removed by a good *varnish-remover*, one of the modern sort, free from alkali. This is painted over the surface, and,

after a short time, removed with a scraper. The last of the varnish-remover is taken out with a rag wet with turpentine or benzine, care being taken that there is no fire of any sort in the room or any neighboring room. This will not only take off the old varnish, but the old filler also; and the floor must be treated like a new floor. Any stains on the floor may be treated with a hot solution of oxalic acid, one part to ten of water; when the stains disappear, wash well with clear water; let the floor dry a day; sandpaper; and it is ready for varnishing again. This treatment—removal of old paint or varnish by a liquid varnish-remover—is applicable to all varnished or painted work. The outside of a house could have the old paint taken off in this way, but *burning off* is cheaper and quicker. These varnish-removers are mixtures of benzole, acetone, alcohol, and other liquids, and the best of them are patented.

ALUMINUM AND BRONZE PAINTS

Radiators and pipes are often painted with aluminum or bronze paints. These consist of metallic powders, in fine flakes, mixed with some varnish—usually with a pyroxylin varnish, which is a thin solution of a variety of gun-cotton in a suitable solvent, generally acetate of amyl. If one of these paints—which smell somewhat like bananas—becomes thickened in the can by evaporation, it can usually be thinned with acetate of amyl, if some of the special thinner cannot be had; brushes can be washed out in the same. A good aluminum paint is durable, even exposed to the weather. One coat is usually enough, two certainly so.

GLAZING

House painters are usually expected to understand the art of setting window-glass; it is not difficult to learn. Glass is classified as *sheet* or *cylinder glass* and *plate glass*. Sheet glass is made, at the glass works, by blowing a quantity of glass, first, into a hollow globe; then, by more blowing and manipulation, this is stretched out into a hollow cylinder perhaps a foot in diameter and five feet long; this cylinder (whence the name "cylinder glass") is cut open, and, after reheating, is flattened out into a sheet, whence the name "sheet glass;" after annealing, it is cut up into convenient sizes. It is made of two

thicknesses—*single thick*, which is about one-sixteenth of an inch; and *double thick*, one-eighth of an inch; but it does not run perfectly uniform. All sheet glass contains streaks, bubbles, and specks of dirt, and is more or less irregular or wavy in its surface; and in respect to this it is graded as first, second, and third quality; in American glass these grades are usually marked "AA," "A," and "B;" and anything poorer than "B" is called *stock sheets*. Foreign glass is not thus marked, each maker having his own arbitrary marks. Single-thick glass is used for sizes not greater than about 28 by 34 inches; double-thick, up to 40 by 60. For larger sizes, plate glass only is used; but of course either plate or double-thick can be used for small sizes, if desired.

Plate glass is cast in plates; the liquid glass is poured out on an iron table, about 15 feet wide and 25 feet long, and smoothed down to a uniform thickness of half or five-eighths of an inch by passing a roller over it, like rolling pie-crust; after this it is ground down with sand, emery, and polishing powder to a quarter or five-sixteenths of an inch in thickness. It is therefore much more costly than sheet glass, but is also more perfect.

Crystal is a very thin plate glass, about one-eighth of an inch thick, and is used where ordinary plate is too heavy, as in movable sash. It is the finest of all window glass. There are two grades of plate glass, known as *glazing* (for windows) and *silvering* (for mirrors), the latter being the best. In the first place, the sash is prepared for the glass. It must receive a priming coat; if it is to be painted, it is primed with white lead and boiled linseed oil, the mixture having very little or no turpentine added; if it is to be varnished, it is primed with boiled oil alone. If it is not primed, the putty will not stick; the wood will draw the oil out of the putty and leave it crumbly. Next, the glass is fitted to the sash. It is cut either with a glass-cutter's diamond or with a wheel cutter, the latter being a little sharp-edged steel wheel set in a handle. If well made, the wheels may be bought separate and are replaceable. The wheel cutters are generally used on sheet glass; but plate glass is cut only with a diamond, which makes a deeper cut. The wheels are kept wet with kerosene; the workman has a little bottle or cup of kerosene on the bench, and dips the wheel in it.

The glass being cut to the right size, a layer of putty is spread, with the putty-knife, along the recess in the sash where the glass is to

rest. This is called *bedding* the glass, and should always be done. It is not uncommonly omitted with pine sash; but it absolutely must be done with all hardwood sash, metal or metal-lined sash, and for all plate and crystal glass; and it ought to be done in all cases. Then the glass is gently pressed into place, after which it is fastened with *glaziers' points*, which are triangular bits of metal. No. 2 points are used on single-thick, and No. 1, which are larger, are used on double-thick glass; they are put in 9 to 12 inches apart. They are driven, not with a hammer, but with the thin side of a two-inch chisel, the flat side of which lies on the glass, the edge of the chisel away from the surface so as to avoid scratching it. The chisel is also useful for adjusting the position of the pane; if it is smaller than the sash, it is so placed that when the sash is in its natural upright position the pane of glass will rest with its lower edge bearing on the wood. The points are commonly of zinc, which bends easily; and when the pane is properly placed, if there is on one side a space between it and the wood, the chisel is held over this crack, and with its edge an indentation or crimp is made in the little triangular zinc point which has already been driven; this crimp prevents the glass from sliding back against the wood. This is the reason zinc is used for the points; it will bend. Steel points are sometimes used for plate glass, because of their greater strength, the glass being heavy. To drive through the sheet metal of metal-covered sash, steel slugs are used; these are about $\frac{1}{10}$ inch thick, about $\frac{7}{8}$ inch long, and $\frac{7}{16}$ inch wide at the wide end, triangular, and sharp-pointed.

There is a machine for driving points, but it is not much used except on small glass set in soft-wood sash.

The glass being properly secured by points, it is ready for puttying. To do this, the professionals set the sash up in a nearly vertical position on an easel; the glass is puttied on the right-hand side and across the bottom; then the sash is turned the other edge up, and the operation is repeated. This finishes the work.

The most important things about glazing are to use a sufficient number of points and to use good putty. Ordinary (pure) putty is made of whiting, which is pulverized chalk, mixed with enough linseed oil to give it the consistence of stiff dough. The workman can make it from these materials with his hands; everyone can make his own putty. As a matter of fact, however, the putty of commerce is made by ma-

chinery; and also, as a matter of fact, it is in general abominably adulterated. It would seem as though whiting and linseed oil were materials cheap enough; and in reality putty can be sold for about three cents a pound, or sixty dollars a ton; and a dollar's worth will putty all the glass in an ordinary house. Pure putty, however, is almost impossible to get. Marble dust is substituted for whiting, and a mixture of rosin and mineral oils for the oil, and the cost reduced about half. It is the use of this miserable stuff which causes nine-tenths of the troubles with windows. If the glazier cannot be sure of his putty otherwise, he should make it himself.

The best putty for glazing is a mixture of pure whiting putty with one-tenth white lead putty. This makes it set a little more quickly, and it becomes harder. Pure white lead putty gets too hard; it is too difficult to remove it in case of breakage of glass.

If the glass has not been bedded in putty, it is customary to go around the indoors side of the glass, and crowd some putty into the crack between it and the sash. This is called *backing* the glass. Large plates of plate glass are not puttied, but are held in place with strips of moulding nailed on the sash, in which case the crack between the glass and the moulding is backed with putty.

REVIEW QUESTIONS

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are samples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for Civil Service Examinations. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

CARPENTRY.

PART I.

1. Give a rule for squaring a log to get the strongest possible timber out of it.

2. What is the "three-four-five rule," and how is it used?

3. Describe (and illustrate by a sketch) a splice suitable for a piece subjected to a bending stress.

4. Why is a "ledger-board" not as good as a "girt" for supporting the ends of floor joists?

5. What are partition caps and soles? What takes the place of the sole when there is a partition directly beneath the one which is being built?

6. Show by a sketch what is meant by "sizing down" a joist onto a girder or sill.

7. What is the method employed for supporting a corner which has no direct support beneath it? Make a sketch of the framing for such a corner.

8. From what two classes of trees is most building lumber obtained?

9. Give a brief description of the following varieties of timber:

a. Cypress

d. Spruce

b. Ash

e. Pine

c. Poplar

f. Oak

10. Name, and show by sketch, five kinds of joints used in carpentry.

11. What must take place before a "fished" splice for tension can be pulled apart?

12. What is a "raised girt?" a "dropped girt?"

CARPENTRY

13. How are furring walls around chimney breasts constructed?

14. Explain one method of framing joists into girders. Girders into sills. Illustrate with sketch.

✓ 15. How are floors "bridged?" Which is the best method? Why?

16. What is the manner of growth of the trees named in Question 9, and in what other way do trees grow?

17. What qualities are required in a wood to be used for light framing?

18. What is "ground water," and why must it be taken into account in the laying out of a building?

19. Show by sketch how the corner of a wooden building may be framed so as to give a nailing for the lathing.

20. At the point where a partition meets an outside wall, what should be the arrangement of the studding? Why?

✓ 21. Explain the method of framing around an opening in the floor frame for a chimney or staircase.

22. Give clear definitions of the following:

- | | |
|------------------|---------------------------|
| a. Pith | e. Heartwood |
| b. Annual Ring | f. Sapwood |
| c. Medullary Ray | g. Cross-grained Timber |
| d. Heartshake | h. Cupshake and Windshake |

✓ 23. What is the "heel" of a steel square? the "blade?" the "tongue?"

24. What are "batter-boards?" Make a sketch of one form of batter-board.

25. How is a "key" employed in a splice for tension? What determines the distance between keys if there are more than one in a single splice?

26. What is the function of the braces in braced frames? Show by a sketch one method of bracing a frame.

27. What is meant by "crowning?" Why is it necessary?

28. Explain the effect of the shrinkage of framing timber, and explain how unequal settlement (due to such shrinkage) may be prevented.

✓ 29. What is the best method of cutting planks from a log? Why?

REVIEW QUESTIONS

ON THE SUBJECT OF

CARPENTRY.

PART II.

1. Give full description of the various forms of roofs, with sketches.
2. Give a rule for obtaining the rise of the rafter in a roof, the span of which is known.
3. Describe the method employed in framing a gambrel roof.
4. What is the "run of a rafter"? What is the rise? What is meant by the pitch?
5. What important property is characteristic of all lines in a roof surface which are parallel to the ridge line? Tell in a general way how this fact is made use of in laying out the valley line.
6. What are the two distances which determine the position of the steel square in laying out valley rafters?
7. What is the principle used in finding the slope of the hip rafter in an "ogee" roof?
8. What is the usual size of rafters for ordinary frame dwellings?
9. Describe a hip rafter. What relation does it bear to a parallel valley rafter in the same roof surface?
10. What is the method of framing adopted for the valley when a small gable intersects a large roof?
11. Describe the different kinds of jack rafters.
12. What must be done to studs forming the framework of an attic partition in order to make them fit the under side of the roof framing?
13. In what does "backing" consist?

CARPENTRY

14. Describe two methods of forming the eaves on frame buildings
15. Describe the framing of a mansard roof.
16. What is the purpose of the ridge-pole and how is it usually made.
17. Describe two different kinds of dormer windows.
18. How are openings made in a roof frame for dormer windows, skylights, etc.?
19. When are trussed partitions used? Describe in a general way their construction.
20. Describe two methods of constructing an "inclined floor".
21. What is the difference between a "king-post trussed beam" and a "queen-post trussed beam"?
22. Describe the construction of a "flitch plate girder".
23. What are the different kinds of rafters used in a roof frame? Describe each.
24. Give a rule for determining the general proportions of a gambrel roof. Illustrate by a sketch.
25. How are rafters of long span strengthened? What are "dwarf walls"? What is a collar beam? Make sketches of same.
26. Describe the construction of a "notched" beam. A "keyed" beam.
27. Explain the difference between a "king-post truss" and a "queen-post truss".
28. How is the curved form given to a bell-shaped or concave tower roof?
29. Is the stress in the king-post of a common king-post truss tension or compression? Of what material is it ordinarily made?
30. Describe or show by a sketch a method of framing a domical roof with provision for a lantern at the top.
31. What is a "groined" ceiling?
32. How far may a balcony or gallery be allowed to project beyond the line of supporting columns without the introduction of a brace?
33. What is the difference between the two connections shown in Fig. 202? What does each depend upon for its strength?

REVIEW QUESTIONS

ON THE SUBJECT OF

STAIR-BUILDING

1. Define *staircase* and *stairway*.
2. What is meant by the *rise* and *run* of a stairway? How measured?
- ✓ 3. Define *tread* and *riser*.
4. How do treads and risers compare as to number? Why?
5. What is a *string* or *string-board*? Describe the various kinds of strings.
6. How are treads and risers fitted together and fastened in housed strings?
7. Describe the construction and use of a *pitch-board*.
8. How are the relative dimensions of treads and risers determined?
9. Are all the risers in a flight of stairs cut of uniform height?
10. Describe the use of *flyers*, *winders*, and *dancing steps*.
11. How are balusters fastened on strings?
12. How are strings fastened to newel-posts?
13. Describe methods of constructing *bullnose steps* and risers for same.
14. What is the difference between a *quarter-space landing* and a *half-space landing*?
15. Define the terms: *well-hole*; *drum*; *cylinder*; *kerfing*; *geometrical stairway*; *carriage timber*; *wreath*; *tangent*; *crown tangent*; *springing of a well-hole*; *ground-line*; *swan-neck*; *face-mould*; *nosing*; *return nosing*; *spandrel*; *cove-moulding*.
16. Describe the use of the *face-mould*.
17. When the face-mould is applied, and material for the wreath cut from the plank, how is the wreath-piece given its final shape?

STAIR-BUILDING

18. What is the use of *tangents* in handrailing? What do the *bevels* represent?
19. What is an *oblique plane*?
20. Are all wreaths assumed to be resting on an oblique plane?
21. In referring to an oblique plane, what do you understand by the expressions *inclined in one direction only* and *inclined in two directions*?
22. What is meant when two wreath tangents are said to be *equally inclined*? What, when *unequally inclined*?
23. When an oblique plane is inclined in one direction only, how many bevels will be needed to twist the wreath?
24. When the plane inclines in two directions, how many bevels are required?
25. When the inclination is equal in two directions, how many bevels are needed?
26. When the plane is *unequally inclined* in two directions, how many bevels are needed?
- ✓ 27. How can a stairway be reinforced?
28. How should a scroll bracket be terminated against the riser?
29. When a plane is *equally inclined* in two directions, how are the bevel or bevels to be applied to twist the wreath resting upon it in its ascent around the well-hole?
30. What is the difference between the *plan tangents*, *pitch-line of tangents*, and *tangents of the face-mould*?
31. Why is it necessary to determine with exactness the angle between the tangents on the face-mould?
32. What is the width of the face-mould to be, when laid out on the minor axis?
33. How is the width of the mould at the ends determined?
34. How do you find the *minor axis* and *major axis* of the mould curves?
35. Show how to find the thickness of the plank that will be required for the wreath.
36. When the plan tangents are at a right angle to each other, and the pitch is equal, how are the bevels to be applied, (1) in relation to each other; (2) in relation to the sides of the wreath?

REVIEW QUESTIONS

ON THE SUBJECT OF

THE STEEL SQUARE

1. On what part of the square will you find the *octagon scale*? Describe its use.
2. On what part of the square will you find the *brace rule*? Describe its use.
3. On what part of the square would you look for the *board measure*? Describe its use.
4. What is meant by the *pitch* of a roof?
5. What is meant by a *bevel* in roof framing?
6. Draw a diagram of a roof, indicating thereon the *ridge*, *common rafters*, *jack rafters*, *hips*, *valleys*, *plate*.
7. How would you lay out a pentagon by means of the square? A hexagon? Illustrate with diagrams.
8. How, with a square, would you find the miter of an equilateral triangle? Of a hexagon? Illustrate with diagrams.
9. What are meant by *plumb cut* and *heel cut*? Draw a diagram to illustrate.
10. Show how to lay out the heel cut of a common rafter.
11. Draw diagrams illustrating use of the square in finding the relative length of run for rafters and hips. Explain.
12. Show how to apply the square to a hip or valley timber to cut the bevel that will fit the top end against the ridge.
13. Describe the application of the square in finding the relative height of a hip or valley per foot of run, to that of the common rafter. Draw a diagram.
14. Describe a method of finding the bevels for purlins in equal-pitch roofs.
15. Describe, with diagram, the use of the square in cutting the back bevel to fit a jack rafter against the side of a hip or valley.

REVIEW QUESTIONS

ON THE SUBJECT OF

HARDWARE

1. What is the difference between a *hinge* and a *butt*?
2. What hardware attachments are desirable when outside window blinds are used?
3. What is the difference between a *lock*, a *latch*, and a *bolt*? How is a latch sometimes made to serve the purpose of a lock? What is a *dead bolt*?
4. What is the difference between a right-hand and a left-hand door?
5. How are door knobs prevented from getting loose?
6. What is meant by *flush* hardware? Give instances of its use. Illustrate, if possible, with diagrams.
7. What are the essential features of a good type of escutcheon?
8. Write a brief historical sketch of the development of the common nail.
9. Describe the different kinds of nails now in common use, noting their relative advantages for different kinds of work and the precautions that should be taken in driving them.
10. Describe the two main classes of locks, with a diagram illustrating each.
11. If you were asked to inspect the window-sash hardware in an up-to-date modern dwelling-house, make out a list of the items you would look for.
12. In joining woodwork, what method is sometimes adopted to overcome the effects of shrinking and swelling?
13. Discuss, giving diagrams, the possibility of the artistic use of strap hinges and tee-hinges.
14. Describe the different classes of door butts, and compare their advantages.

REVIEW QUESTIONS

ON THE SUBJECT OF

PLASTERING

1. Describe the proper method of spacing, nailing, and joining wood lath.
2. Of what materials is mortar composed? What are the requirements of each to insure good results?
3. Compare the relative advantages of metal and wood lathing for both interior and exterior plastering.
4. How are estimates for lathing and plastering made?
5. What precautions are absolutely necessary in the placing of metal lath?
6. If wood lathing is used on exterior work, how should it be laid?
7. When, if ever, is wire lath preferable to expanded metal?
8. Describe in detail the process of slaking the lime and mixing the mortar for ordinary interior plaster work in dwelling-houses. What precautions are to be observed?
9. Should mortar be used as soon as mixed? Discuss this question in all its bearings.
10. How would you mix the mortar for exterior work?
11. If lime is not thoroughly slaked, what trouble is likely to develop?
12. What will be the effect of using too much lime in mixing mortar? too much sand?
13. What are the essentials for durable exterior plastering?
14. Discuss the relative advantages of three-coat and two-coat work. In what kind of work are three coats always necessary?
15. In interior work, what precautions must be observed in laying the successive coats of plaster? In exterior work?

REVIEW QUESTIONS

ON THE SUBJECT OF

PAINTING

1. What is the difference between raw and boiled oil? When is one preferable to the other?
2. What would you consider a good brush outfit for painting and varnishing the interior woodwork and exterior finish of a modern frame dwelling?
3. How would you make your own putty if you could not buy a satisfactory grade?
4. Describe the principal ingredients used as *pigments*. As *vehicles*.
5. What are *thinners*? *Dryers*? *Fillers*?
6. How are painters' brushes kept in good condition?
7. How are paints adulterated?
8. Describe the process of mixing the successive coats of paint for ordinary interior (not floor) and exterior woodwork.
9. Describe the process of preparing the woodwork and applying the successive coats of paint in ordinary interior (not floor) and exterior work.
10. What points require particular attention in the repainting of an old job?
11. Describe the process of painting a plastered wall.
12. Describe the material and methods of work in roof painting.
13. What is enamel paint? How would you do a job of enameling the woodwork, say, in a bathroom?
14. Describe in detail the process of painting structural metal.
15. How are varnishes classified?
16. Describe the method of preparing and applying shellac varnish,

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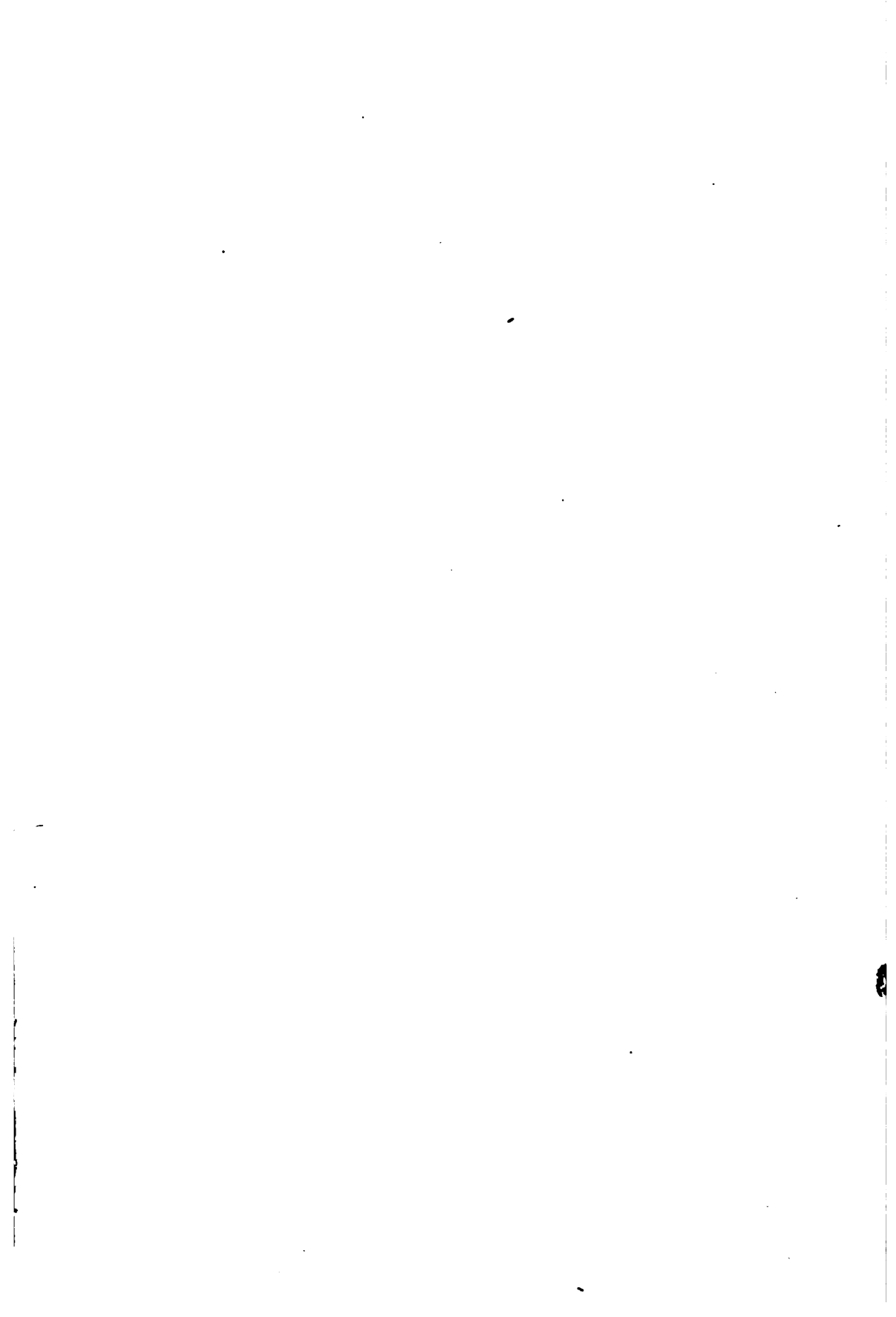
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